X-RAY DIAGNOSIS

A Manual for Surgeons, Practitioners, and Students

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With 80 Skiagraphic Plates

PREFACE

In writing this book I have endeavoured to outline the guiding principles of Radiographic Diagnosis in the examination of those tissues whose structure renders them demonstrable by X-radiation. With this aim in view, the descriptions of the lesions affecting the different anatomical systems are preceded in every instance by an analysis of the appearances produced by the normal structure, and of the modifications in those appearances which result from disease. It is hoped that a basis for logical interpretation is in this way provided.

In a work of this size it is obvious that consideration of the rarer lesions must be brief, but an attempt has been made to deal adequately with all those conditions which are encountered at all frequently.

No detailed description of technique is included, except where necessary for the proper understanding of the methods employed, since there are already many excellent textbooks largely devoted to the management and use of radiographic apparatus. It must be remembered that the ultimate aim of the examination is the formation of a reasoned diagnosis, and that without the requisite knowledge to arrive at this end the most perfect technical results are of no avail.

My hope is that the book may prove useful to the Surgeon and the Practitioner whose work brings them into constant touch with Radiology, but who have had neither the time nor

facilities for making a special study of the subject; to the Post-graduate preparing for the higher medical and surgical examinations and the diplomas in Radiology now granted by Cambridge and Liverpool Universities; and to the Under-graduate studying for the pass examinations, to whose curriculum of obligatory subjects Radiology has lately been added.

<div align="right">J. M. R.</div>

August, 1926.

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X-RAY DIAGNOSIS

CHAPTER I

INTRODUCTORY

RADIOGRAPHIC DIAGNOSIS depends on the variable penetrability of the tissues of the body to X-radiation, and the translation of this penetrability into a visual record of varying opacities.

Two methods are available for recording these opacities—the fluorescent screen and the photographic plate—and the respective merits and demerits of these two media for radiographic interpretation require some preliminary consideration.

Fluoroscopy possesses one great virtue, in that it enables the structures under examination to be observed in motion ; it therefore forms an important part of the examination of the cardio-vascular, respiratory and alimentary systems. Against this asset, and without detracting from its value, must be set the following disadvantages :—

1. The image on the fluorescent screen is transitory, and the interpretation of the image must therefore depend on the conception formed by the operator as the result of a brief visual impression.

2. The fluoroscopic image is exceedingly poor in detail as compared with a successful skiagram. So great is this disparity in detail that fluoroscopy should be denied any place whatever in the examination of the skeletal system.

3. Fluoroscopy is attended by the risk of damage to both patient and operator ; reasonable application of the plate method by a skilled operator using a properly protected apparatus can be considered as free from any danger.

The **skiagram** of good quality provides a permanent record which can be examined at leisure in circumstances the most favourable for considered interpretation ; it shows perfect detail in tissue structure within the limits of the radiographic method, and records small variations in opacity which are quite invisible on the fluorescent screen.

In brief, it can be asserted that the skiagram forms the essential basis for radiographic diagnosis ; that in examinations of the respiratory, cardio-vascular and alimentary tracts skiagraphy must be combined with fluoroscopy, this latter being as restricted in duration as possible ; and that a diagnosis even of these parts should never be made on fluoroscopy alone.

Examination by the plate method must conform to certain generalizations, otherwise the skiagram may be as misleading as the fluoroscope image.

Firstly, the skiagram must be of good quality, the result of first-rate radiographic and photographic technique.

Secondly, whenever possible the skiagram should be obtained by a method rigidly standardized as regards the position of the part examined, the relation of the part to the central radiation of the tube, and the position of the plate. In this way only is it possible to produce an identical picture of any normal part at every examination, the recognition of abnormality being thus greatly simplified.

Thirdly, in all examinations of the skeletal system two views at right angles should be obtained whenever possible. The shoulder and pelvic girdles, and the upper dorsal spine, are the only parts where but one view is possible in the normal individual. Splinting and immobility from other causes may render the two-view method impossible in some cases, and it is in such instances that *stereoscopic skiagrams* are of some value.

Stereoscopy should, however, be limited to such cases : it should never take the place of the two-view method where this is practicable.

Interpretation of the skiagram depends on a carefully considered analysis of the skiagraphic appearances, leading to the conclusion either that these appearances are normal, or that they are abnormal ; in the latter case the quality of the abnormal appearances must be analysed before attempting to translate the skiagraphic image into terms of pathology.

The details of this analysis necessarily vary in the examination of different structures (e.g. bone, lungs), and will be dealt with in their appropriate sections, but it must be emphasized here that careful analysis of skiagraphic appearances is the only means at our disposal for radiographic diagnosis : in no branch of Medicine is the " spot-diagnosis " a more fruitful source of error than in radiology.

The radiologist must go a step farther with his interpretation : he must form a just estimate of the value attaching to his examina-

tion in any particular case. This value may be absolute, as in fractures or dislocations in most parts of the skeletal system ; the value may be negligible, as in failure to demonstrate a lesion of the biliary tract ; perhaps most frequently the examination is of some value intermediate between these extremes. The limitations of radiology are considerable, and must be frankly and openly recognized.

The correlation of the radiographic diagnosis with the clinical features of any particular case is, of course, an essential, but should follow, not precede, the analysis and interpretation of the skiagram. The author is convinced that an unbiased analysis of the skiagram is impossible by one who has already made a clinical diagnosis, and it is only by such unbiased analysis that the individual observer can attain any degree of accuracy in radiology.

CHAPTER II

NORMAL APPEARANCES OF BONES AND JOINTS. OSSIFICATION. DEVELOPMENTAL ABNORMALITIES

THE structure of bone is beautifully demonstrated in a skiagram of good quality, and persistent effort must be made by means of constant study of the normal to memorize the detailed appearances of all parts of the skeleton. These details naturally vary to a very marked degree in the different elements, being an expression of the stresses and strains which the bone is designed to support; but it follows from this conception of structure that the details in the same bone of any number of normal individuals must show a strong similarity. This is borne out by practical investigation.

If these variations in detailed structure be disregarded for the moment, a general description of normal bone appearances can be given.

In the shafts of the long bones the cortex, the underlying cancellous bone, and to some extent the medullary cavity, are quite clearly differentiated.

The *cortex* produces a dense opacity, with perfectly smooth peripheral (subperiosteal) margins, and rather abrupt internal limitations where it becomes continuous with the underlying cancellous bone. In the larger and more deeply situated bones this cortical opacity may appear almost homogeneous, but examination of the cortex of one of the smaller long bones will reveal a definite lamellar striation, parallel with the long axis of the shaft. The width of the cortex undergoes gradual diminution towards the articular extremities.

The *cancellous bone* forms a comparatively thin layer in the central portions of the shaft, blending with the cortex externally and presenting an ill-defined internal margin where it surrounds the medullary canal. The structure of the cancellous bone is that of a fine-meshed irregular network of lamellæ; it is seen to much greater advantage towards the articular extremities, where the width of cancellous bone is increased at the expense of the cortex and the medulla. In such a situation the lamellar network can be seen in perfect detail.

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Normal long bones and epiphyses.

PLATE 1.

The *medullary canal* is never seen in the skiagram free from bone-shadow, owing to its central position, and can only be recognized as a central area of comparative translucency, blending imperceptibly with the surrounding cancellous structure.

In the articular extremities of the long bones the cortex is reduced to a thin layer, and cancellous structure becomes the predominant feature. In most situations it will be found that the cancellous bone of the articular extremities assumes a specialized and constant structure, the irregular laminar network being reinforced by long and dense lamellæ disposed in an orderly and purposeful pattern. This is particularly well seen in the neck of the femur, but to a less extent can be demonstrated in most of the articular extremities. (Plate 1.)

In the *cancellous bones*, such as the tarsus, a very thin cortical layer is demonstrated, surrounding the cancellous structure which forms the bulk of the bone. The cancellous structure is modified by long, dense lamellæ, as in the articular extremities, in certain situations ; this modification is especially obvious in the os calcis, but can be made out in most of the tarsus, and in the bodies of the lower vertebræ.

The *flat bones* present the appearances of cancellous structure unless seen in profile, in which case the cancellous bone is seen enclosed between two cortical layers. The flat bones forming the vault of the skull possess special features which will be considered in a later chapter.

In a *joint of a normal adult* the articular surfaces are seen to be composed of a thin but dense cortical layer, possessing a perfectly smooth free surface.

The articular extremities forming the joint are separated by a translucent zone which is, in fact, occupied by the opposing articular cartilages, normal cartilage being for practical purposes non-opaque to X-radiation. The depth of the joint-space varies in the different articulations, but is remarkably constant in the corresponding joint of any number of adults. Diminution in width of the joint-space indicates erosion of the articular cartilages, and a clear conception of the normal width in the different joints is therefore of prime importance.

In the *early years of life*, before ossification of the epiphysial nuclei is completed, the bony articular extremities are separated by a translucent zone which is greater than the adult joint-space, and which gradually diminishes as ossification proceeds. This wide translucent zone represents the joint-space together with the unossified cartilage of the epiphyses entering into the articulation. As the extent of ossification is inconstant in different individuals of the same age, minor variations in the depth of the translucent zone cannot be taken as indicating an articular abnormality ; but this can often be deter-

mined by comparison with the corresponding joint on the other side of the same subject. It must, however, be remembered that a good deal of asymmetrical ossification is frequently found in normal children, especially during the first decade.

The skiagraphic appearances of the developing joint are strikingly dissimilar from those of the adult joint in another respect.

It has been stated above that the adult articular extremity is covered with a thin layer of dense cortical bone presenting a smooth surface. In the developing joint the articular extremity consists of cartilage : the margins of the bone-shadow represent the limits of ossification into that cartilage, and are often very irregular. This irregularity of ossific extension towards the articular surface of the epiphysis is often very obvious in the knee-joint, and failure to recognize the nature of the irregularity has led to many erroneous diagnoses.

OSSIFICATION OF THE SKELETON

The details of ossification during fœtal life will not be entered into here, as this subject is of academic rather than of practical interest to the radiologist in the present imperfect state of our knowledge.

A thorough acquaintance with the normal process of ossification during postnatal life, and the variations commonly encountered, is, however, essential for the correct interpretation of bone skiagrams of young subjects. Radiology has proved that the usual anatomical tables of dates for appearance of epiphysial nuclei require a certain amount of modification ; and has also shown the frequency of variation from the commonly accepted views as to the number and disposition of these nuclei. The following account of ossification is based on radiographic appearances noted over a considerable period of time. Details of ossification which cannot be demonstrated in the skiagram are only briefly mentioned.

THE SKULL

The *occipital* bone at birth consists of four parts, the tabular portion, two condylar portions,· and a basilar portion. The tabular portion usually shows partial division into upper and lower parts ; the upper part may remain completely separate throughout life, forming the interparietal bone.

The division between the tabular and condylar portions is seen in a skiagram, but the two condylar portions cannot be differentiated, and both are largely obscured by the shadow of the temporal bone. The division between the condylar portions and the basilar portion is also obscured, but that between the latter and the sphenoid is well shown.

No division can be seen between the portions of the occipital bone after the fourth year.

Skull at birth.

PLATE 2.

The *parietal* bones at birth show complete ossification up to the margins of the surrounding sutures.

The *frontal* bone at birth consists of two lateral portions which fuse from below upwards. Fusion is usually complete about the third year, but a suture (the metopic) may persist throughout life.

The *temporal* bone at birth consists of four parts—squamous, petro-mastoid, and two centres in the styloid process. In the skiagram no division can be made out between the petro-mastoid and squamous portions, while the styloid nuclei are not demonstrated until later in life. The nucleus for the lower portion of the styloid process is, however, of interest to the radiologist, since the two portions of the styloid do not unite until puberty, and not infrequently remain separate throughout life. Pneumatic cells are not, of course, seen in the mastoid portion of the temporal bone at birth, but are sometimes visible as early as the end of the first year.

The *sphenoid*, seen in a lateral view of the skull, appears at birth as a single, somewhat oblong bony mass, with clear separation from the frontal bone and basi-occiput. The sella turcica is well developed. The sphenoid is not well seen in a postero-anterior view of the skull in early life, and the three parts of which it is composed at birth can therefore hardly be differentiated.

The *bones of the face and nasal fossæ* do not show readily distinguishable shadows at birth. The alveolar process of the superior maxilla, however, forms quite a well-marked opacity, honeycombed with translucent areas representing the follicles of the temporary teeth. These teeth can be made out in the follicles. The mandible at birth is seen to consist of two lateral halves, but otherwise is fully ossified. The temporary teeth in their follicles are seen as in the maxilla.

The width of the *sutures* in the normal skull at birth varies in different individuals from $\frac{1}{4}$ in. to $\frac{1}{2}$ in. The bony margins abutting on the sutures lack the serrated edges seen in later life; these, however, are apparent by the end of the first year, by which time the sutures are usually all closed. The anterior fontanelle occasionally remains unossified to the end of the second year. (Plate 2.)

Developmental variations and abnormalities.—Accessory ossicles or Wormian bones are by no means infrequent, and are usually visible at birth. The pterion ossicle, situated at the junction of the anterior inferior angle of the parietal bone with the great wing of the sphenoid and frontal bone, is the most common. The asterion (the point of junction of the posterior inferior angle of the parietal bone with the occipital and mastoid bones) is another common site for a Wormian ossicle. Occasionally these ossicles occur also along the lines of the sutures and may be very numerous.

The Spinal Column

The *atlas* at birth consists of two lateral masses, the anterior arch not beginning to ossify until the first year. The odontoid process of the axis is, however, well seen, lying between the lateral masses of the atlas and separated from the body of the axis. The *axis* consists of three pieces, a body and two lateral masses. The division between the body and the odontoid process cannot be demonstrated after the first year. Each vertebra from the 3rd cervical to the 5th lumbar consists of three pieces at birth—the body and two lateral masses ; while the three upper sacral vertebræ consist of five pieces each—the body, two lateral masses and two laminæ. The 4th and 5th sacral vertebræ usually consist of three pieces each at birth, one for the body and two for the laminæ. All these can be distinguished radiographically. (Plates 3, 4.)

The laminæ of the *cervical, dorsal and lumbar vertebræ* become united behind in the first year. The bodies and neural arches are first joined in the upper cervical region, beginning in the third year, and union proceeding down to the lumbar region, where it is not complete until the sixth year. Radiographically, however, no definite division can be seen between the portions of any of these vertebral bodies after the second or third year.

The laminæ of the *sacral vertebræ* become united with each other behind, and with the bodies in front, from the second to the fifth year, beginning below ; but radiographically each sacral vertebra appears as a single bone by the third or fourth year.

Ossification of the sacrum into a single bone occurs by the twenty-fifth year, sometimes earlier.

The *coccyx* ossifies from four centres, one for each piece. The centre for the first piece is stated to appear soon after birth, but radiographically is not seen much before the fifth year. The second piece is seen at the age of 7–10 years, the third piece about the fifteenth year, and the fourth piece from the eighteenth to the twentieth year.

Secondary ossific nuclei occur in the vertebræ as follows :

The axis : One for the tip of the odontoid process in the second year, joins the process in the twelfth year. This is not demonstrated radiographically. A thin epiphysial plate develops on the under-surface of the body about the sixteenth year.

The 3rd cervical vertebra to the 5th lumbar :

One for the tip of each transverse process,	Fourteenth
One for the tip of the spinous process,	to
One for the upper and one for the lower surface	sixteenth
of each vertebral body.	year.

The lumbar vertebræ have two additional centres each for the
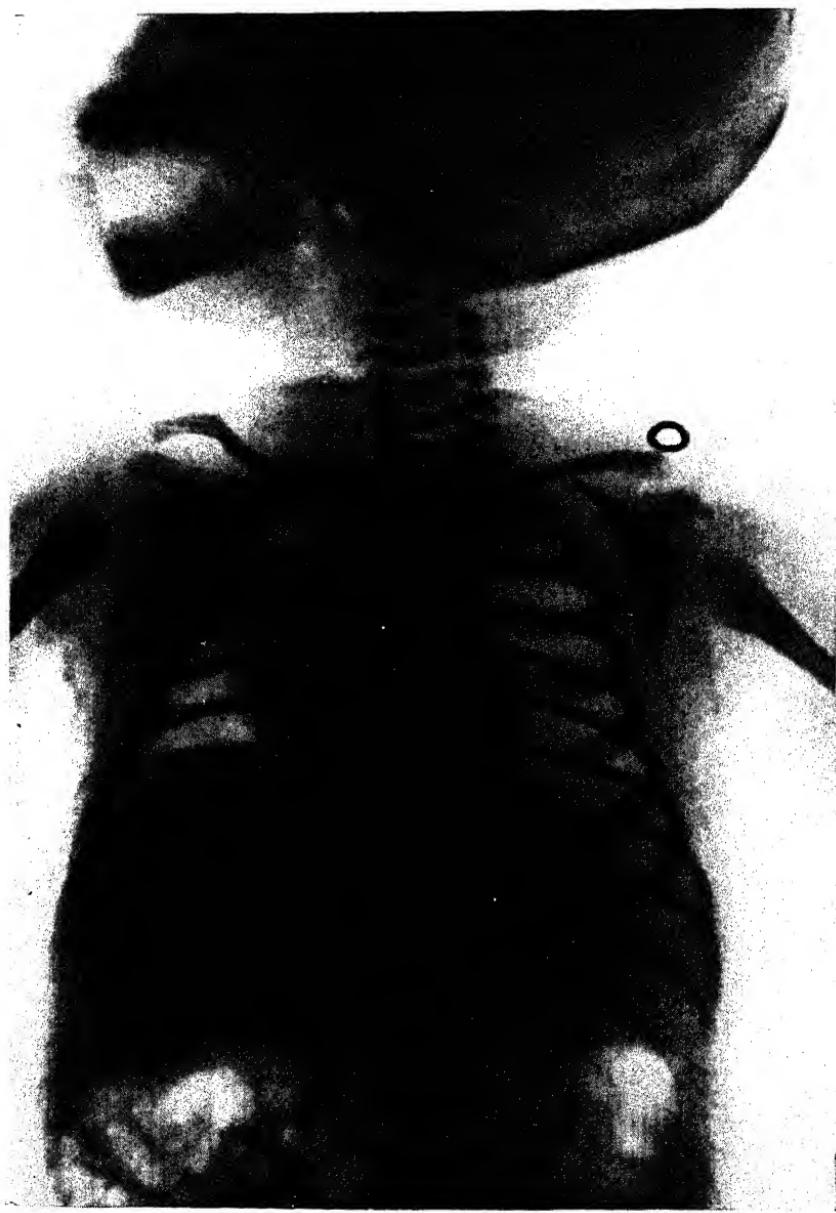
Upper part of trunk at birth.

PLATE 3.

Lower part of trunk at birth.

PLATE 4.

mammillary processes, projecting back from the superior articular processes.

The secondary centres in the cervical spine are not well seen radiographically, and the centres for the mammillary processes of the lumbar vertebræ are not demonstrated at all, but all the other secondary centres can be made out.

The centres for the plates on the upper and under surfaces of the vertebral bodies are of considerable interest in relation to obscure spinal affections. The centres are first seen in the mid and lower dorsal regions as small triangular nodules of bone at the anterior extremities of the upper and lower margins of the bodies. From these nodules ossification spreads backwards fairly rapidly to form thin, fairly regular plates.

Anatomically the secondary centres are said to fuse with the vertebræ at about the age of twenty-five, but radiographically the separation is lost much earlier.

The *sacrum* has the following secondary centres :

One for the auricular portion of each lateral margin,

One for each lateral margin below the auricular surface.

Eighteenth year.

These are not often seen radiographically ; an appearance suggesting a double margin to the sacro-iliac synchondrosis is, however, sometimes noted about the eighteenth to the twentieth year, and is presumably due to the presence of the epiphysial plate for the auricular surface.

Developmental variations and abnormalities are common in the spinal column. In the cervical region a separate centre of ossification sometimes appears for the anterior part of the 7th cervical transverse process, on one or both sides. This may remain ununited throughout life, forming a cervical rib, or may fuse with the transverse process, which is then frequently elongated. Cervical ribs vary from minute nodules to a size approximating to that of the 1st dorsal rib. In the latter case the appearances may be somewhat misleading, but a correct diagnosis can be made by noting the position of the anterior extremity of the rib, and remembering that the 1st dorsal rib always retains its normal relationship to the manubrium sterni.

Lumbar ribs, generally unilateral, are sometimes seen in connexion with the 1st lumbar vertebra. They are generally short and of very slender proportions.

The 5th lumbar vertebra shows many and frequent variations in form ; it is very commonly asymmetrical, both as regards the body and its process. The transverse processes are often of

considerable size, and may simulate the lateral masses of a sacral vertebra; they sometimes have definite articulation with the first piece of the sacrum, or may abut on the adjacent iliac crest. Many "backaches" have been ascribed to these enlarged transverse processes, but their rôle in the production of lumbo-sacral pain remains problematical. It must be remembered that these enlargements are very common; and that the overlapping of shadows in an antero-posterior view does not mean that the parts concerned (i.e. transverse processes and ilium or sacrum) are necessarily in close relationship to one another: there may be wide separation in an antero-posterior plane. No lateral view of sufficient quality to elucidate this point can be obtained, while stereoscopic skiagrams of this region are notoriously misleading.

The direction of the lumbo-sacral articular processes sometimes approximates on one or both sides to that of the processes in the upper lumbar spine, and this may have some bearing on the liability to spondylolisthesis, described in a later chapter. The angle formed by the 5th lumbar vertebra and sacrum undergoes a gradual increase from childhood to early adult life, but is exceedingly variable in its ultimate magnitude.

The most common variation seen in the 5th lumbar vertebra is failure of fusion of the neural arch. This occurs with great frequency, and cannot be regarded, *per se*, as having any significance. A similar lack of fusion is often apparent in the 1st sacral neural arch.

In subjects who show clinical evidence of spina bifida the skiagram commonly demonstrates gross deficiency of the neural arches of more than one vertebra, often associated with deformity of the vertebral bodies. (Plate 5, Fig. 1.)

Half-vertebræ are most commonly seen in the dorsal region, but also occur in the cervical and lumbar spine, and are frequently multiple. In an antero-posterior view they present the typical wedge shape, producing an angular lateral deviation of the spine, and in the dorsal region generally bear a supernumerary rib, which may or may not present a normal appearance. Half-vertebræ in the dorsal spine are often associated with multiple deformities of ribs, such as fusion of adjacent bones, and abnormalities in length and girth. (Plate 5, Fig. 3.)

An extra vertebra of normal structure is fairly common in the lumbar region, but rare in other parts of the spine.

Fusion of two lumbar vertebræ is rather rare, and must be differentiated from ankylosis due to old disease. The complete continuity and regularity of lamellar structure in the fused vertebræ, and the absence of any angulation in either antero-posterior or lateral views, should establish the diagnosis without difficulty. (Plate 5, Fig. 2.)

Fig. 1.—Spina bifida.
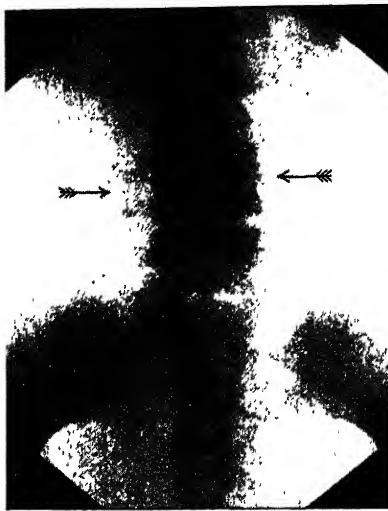
Fig. 2.—Development fusion of two lumbar vertebræ.
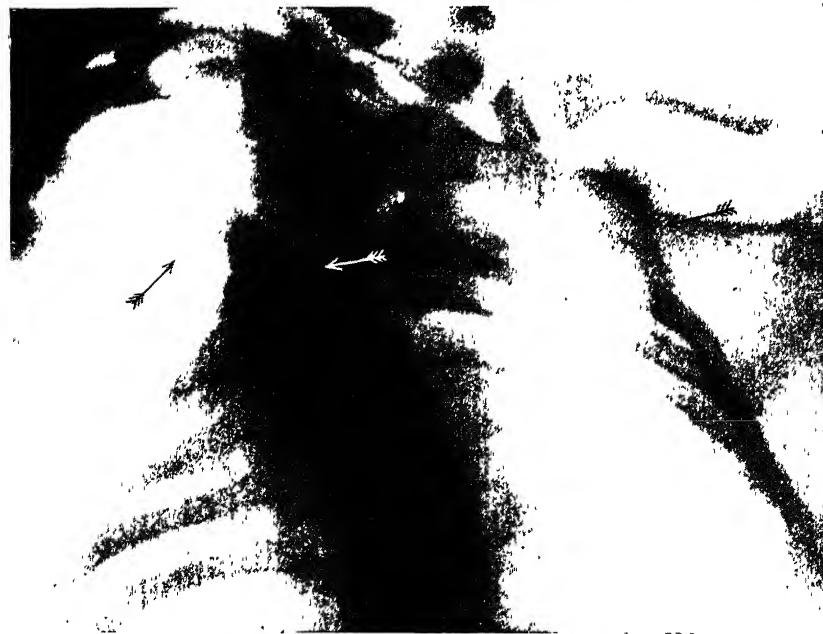
Fig. 3.—Half-vertebra and partial fusion of two ribs.

PLATE 5.

Until about the twelfth year the vertebral bodies in the mid and lower dorsal regions (and occasionally in the upper lumbar regions) frequently show a partial horizontal cleft, extending more or less deeply backwards from the anterior surface. This is apparently a perfectly normal appearance, but is difficult to explain anatomically. (Plate 6, Fig. 1.)

The Ribs and Sternum

The *ribs* develop from a single primary centre which appears very early in fœtal life. At birth the ribs appear fully ossified. Secondary centres for the head and tubercle appear about the sixteenth year, but are not demonstrated as distinct nuclei in a skiagram (the 11th and 12th ribs have only one secondary centre, that for the head). The costal cartilages are not seen in a skiagram until some degree of calcification has taken place. This occurs quite early in adult life in the cartilage of the 1st rib, but in the lower ribs varies greatly in time of appearance. The calcification, even when extensive, is always incomplete, producing an irregular opacity made up of a number of small discrete spots. Calcification becomes much more nearly complete in the cartilage of the 1st rib than in any other.

Developmental variations and abnormalities of the ribs.—The characteristics of cervical and lumbar ribs have been described above, and the occurrence of deformities of the ribs in association with half-vertebræ has also been noted. (Plate 5, Fig. 3.)

Partial fusion of one or more ribs, forming a broad plaque of bone, is sometimes seen in the absence of any abnormality in the spinal column ; and one or more ribs may be unduly short, with a consequent obvious clinical defect in the anterior part of the bony thoracic wall.

The *sternum* usually develops from six centres—one for the manubrium, one for each piece of the gladiolus (four in all), and one for the ensiform cartilage. The four upper nuclei are present at birth, and the fifth appears in the first year of extra-uterine life. The centre for the ensiform cartilage is sometimes absent ; if present it does not appear until about puberty. The sternum is a difficult bone to demonstrate satisfactorily, and the difficulty increases with the size and age of the subject. By the end of the first year it is usually possible to demonstrate three or four small rounded nodules representing the manubrium and upper portions of the gladiolus. By the fourth year all parts of the gladiolus are well seen. The ensiform can rarely be demonstrated, even in the adult. Complete bony fusion of the pieces of the gladiolus is seen between the ages of twenty and twenty-five. A definite space is generally apparent between manubrium and gladiolus throughout life.

Developmental abnormalities of the sternum.—Varying degrees of separation of the sternum into two lateral halves are sometimes encountered, and can be demonstrated radiographically in favourable circumstances.

The Clavicle and Scapula

The *clavicle* develops from two centres, one for the shaft, which appears very early in fœtal life, and one for the sternal extremity, which appears about the eighteenth year. This is said to unite with the shaft at the twenty-fifth year, but radiographically no separation can generally be seen later than the twentieth year.

At birth the clavicle is completely ossified except for the sternal extremity ; but owing to lack of ossification in the acromion process of the scapula the outer end of the clavicle appears to be at a higher level in relation to this process than obtains in later life.

The *scapula* develops from seven centres : One for the body early in fœtal life. Two for the coracoid process—one for the apex in the first or second year, one for the base at the fifteenth year. Two for the acromion process, fifteenth and sixteenth year. One for the vertebral border, seventeenth year. One for the inferior angle, sixteenth year. Sometimes a centre appears for the upper part of the glenoid cavity, and an epiphysial plate for the lower part of the glenoid cavity.

At birth the scapula is extensively ossified. (Plate 3.) The glenoid cavity is somewhat insignificant, the acromion process is noticeably short, and the increased density due to the coracoid process in the adult is missing. The secondary centres can all be made out in the skiagram under favourable circumstances. It is noteworthy that the centres for the acromion form only a small portion of that bone, appearing as small nodules at the anterior and outer margins of the process, which has become almost completely ossified by extension outwards from the primary centre.

The secondary centres are fused with the body of the bone about the twenty-fifth year. They can rarely be recognized radiographically later than the twentieth year.

Developmental abnormalities of the scapula.—The scapula may show simple elevation in the condition known as "Sprengel's shoulder," or there may be multiple deformities of ribs, scapula and cervico-dorsal spine. Bony continuity of the scapula with adjacent parts is rarely demonstrated.

In congenital dislocation of the shoulder-joint there is a typical scapular deformity, the acromion process forming a hook-like projection bent downwards at a sharp angle over the outer aspect of the glenoid cavity. The appearance is distinctive, quite apart

Fig. 1.—Normal dorsal spine of child aged 3 years, showing horizontal cleft in vertebral bodies.

Fig. 2.—Congenital dislocation of shoulder.

Fig. 3.—Madelung's deformity.

PLATE 6.

from the downward displacement of the head of the humerus. (Plate 6, Fig. 2.)

THE HUMERUS, RADIUS AND ULNA

The shafts of these bones are each developed from a single centre appearing early in fœtal life, and are completely ossified at birth. The articular extremities require more detailed consideration.

The *upper extremity of the humerus* is ossified from three centres :

> One for the head, which usually appears early in the first year, but may be quite obvious at birth. (Plate 3.)
>
> One for the greater tuberosity, about the third year.
>
> One for the lesser tuberosity, about the fifth year.

These fuse about the sixth year to form a single epiphysis, which unites with the shaft at the twentieth year. Radiographically, the centre for the head is the dominant feature of the upper humeral epiphysis. By the third to the fifth year an extension of ossification downwards is seen on the outer aspect of the epiphysis, forming the greater tuberosity. This often appears directly continuous with the centre for the head of the humerus, and possibly this is sometimes actually the case. Examination of the humerus in external rotation will, however, often demonstrate a faint line of demarcation between this lateral extension and the head of the bone, indicating the presence of a separate ossific nucleus for the great tuberosity. The centre of ossification for the lesser tuberosity cannot be demonstrated in the skiagram. From about the seventh to the eighteenth year the upper end of the humerus presents, in the views usually obtained, a double epiphysial line, due to the fact that the anterior and posterior margins of the epiphysial cartilage are not directly superimposed. This double line is a frequent source of confusion and of erroneous diagnosis of fracture.

Developmental abnormalities of the humerus.—The typical deformity of the acromion process in congenital dislocations of the shoulder-joint has been noted above. The upper epiphysis of the humerus in this condition is generally smaller than normal, and ossification may be late. The displacement downwards of the head of the humerus in relation to the glenoid cavity is apparent as soon as the ossific nucleus can be made out. (Plate 6, Fig. 2.)

The *lower end of the humerus* ossifies from four centres :

> One for the capitellum and adjacent portion of the trochlear surface, in the second year.
>
> One for the internal epicondyle, in the fourth year.
>
> One for the major portion of the trochlear surface, in the eighth to the tenth year.
>
> One for the external epicondyle, about the fourteenth year.

The centres for the capitellum, trochlear and external epicondyle become fused into a single epiphysis about the sixteenth year, and soon afterwards join the shaft.

The centre for the internal epicondyle remains distinct until it joins the shaft about the eighteenth year.

Radiographically the trochlear ossific nucleus is of interest in that it usually presents an irregular, ragged outline and punctate opacity from its first recognition up to about the tenth year, by which time the outlines of the nucleus are generally smooth and regular and the structure continuous throughout. The appearance of this nucleus in early life suggests the presence of a great number of minute areas of ossification, rather than orderly extension from a single ossific centre.

The external epicondylar centre is small, and only distinguishable as a separate entity for a short period between its first appearance and early fusion with the external condyle.

The *upper end of the radius* ossifies from a single centre which appears about the end of the second year, shortly after the appearance of the centre for the capitellum of the humerus.

The *upper end of the ulna* is ossified almost entirely from the primary centre for the shaft, and is well formed at birth. The tip of the olecranon process is ossified from two or three small nuclei which appear about the tenth to the twelfth year, and fuse into a single epiphysis within a year or two. This epiphysis unites with the shaft about the sixteenth year. Sometimes the epiphysis ossifies from a single nucleus, but multiple nuclei are more commonly seen.

The *lower end of the radius* ossifies from a single centre which appears in the second or third year. The ossific nucleus soon assumes a wedge shape, the base of the wedge, from which ossification extends into the radial styloid process, forming the outer aspect of the radial epiphysis.

The *lower end of the ulna* ossifies from a single ossific centre which rarely appears before the seventh year. Ossification generally commences about the centre of the head of the ulna, but may be first seen at the base of the styloid process.

Developmental abnormalities of the radius and ulna. — Congenital dislocation of the head of the radius is occasionally seen. The displacement is usually backwards, as opposed to the forward direction of traumatic dislocations. The upper extremity of the radius shows considerable deformity in late childhood and adult life in cases of congenital dislocation, but this is not inconsistent with a longstanding lesion of traumatic origin.

Synostosis of the upper ends of the radius and ulna is not very uncommon. The bones are generally united about the level of the bicipital tubercle on the radius, over a comparatively small area.

The upper extremities are usually separate, but may show some degree of malformation.

The lower end of the ulna is sometimes defective, or the whole bone may be absent, although a small nodule representing the upper extremity can usually be seen.

Madelung's deformity is generally bilateral. The inferior articular surface of the radius is directed obliquely forwards, and also slopes upwards towards the inner side. The radial facet for the inferior radio-ulnar joint is deformed, and the lower end of the ulna projects backwards. (Plate 6, Fig. 3.)

THE CARPUS

Each of the carpal bones ossifies from a single centre. The average times of appearance in a skiagram are as follows :

Os magnum	First year.	Trapezium	Fifth year.
Unciform		Trapezoid	Fifth to seventh
Cuneiform .	Third year.	Scaphoid	year.
Semilunar .	Third to fourth year.	Pisiform .	Tenth year.

Developmental abnormalities of the carpus.—Accessory ossicles in the carpus are not very common ; the os triangulare is that most often seen, and lies immediately distal to the styloid process of the ulna. It is distinguished from an old ununited fracture by the fact that the styloid process itself is of normal length. It must be remembered, however, that the length of the styloid process varies considerably in different individuals. The os centrale lies between the os magnum and distal portion of the scaphoid. Sometimes a small projection is seen from the os magnum, possibly representing an os centrale which has fused with the larger bone. Very rarely an ossicle is seen internal to the base of the 5th metacarpal, analogous to the os Vesalii of the foot.* A separate ossicle, the radiale externum, sometimes forms the end of the tubercle of the scaphoid, but the "divided scaphoid" which has been described is probably pathological (i.e. old ununited fracture). Accessory ossicles in the carpus, as elsewhere, may be either unilateral or bilateral.

THE METACARPUS AND PHALANGES

The shaft of each of these bones is ossified from a single centre appearing early in foetal life. Secondary centres appear as follows :

> One for the base of the 1st metacarpal, third year.
> One for the head of each of the other metacarpals, third year.
> One for the base of each phalanx : 1st row, first to third year ; 2nd and 3rd rows, fourth to fifth year.

* Howard Pirie, *Am. Journ. of Roentgenology*, 1921.

These epiphyses unite with the shafts about the eighteenth to twentieth year.

The sesamoid bones in front of the head of the 1st metacarpal are ossified by the fourteenth year. The sesamoid bones in front of the 2nd and 5th metacarpals, and that in front of the head of the 1st phalanx of the thumb, are not constant, and if present do not appear till somewhat later.

Developmental variations of the metacarpus.—Extra epiphyses are very common for the head of the 1st and for the base of the 2nd metacarpals. Extra epiphyses are sometimes seen at the bases of one or more of the three inner metacarpals, but these are rare.

These extra epiphyses appear about the third or fourth year, and generally unite with the shafts fairly early.

A partial cleft is often seen in the base of the second metacarpal, probably indicating a rudimentary basal epiphysis, no complete separation ever having been present.

The Os Innominatum

This bone develops from three primary centres which appear early in fœtal life, one each for the ilium, ischium and pubis. At birth the pubic and ischial rami are very largely cartilaginous, as is also the floor of the acetabulum ; this is represented in the skiagram by a wide space between the ilium above and the ischium below, ossification in the pubic bone being confined to the body and the immediately adjacent portions of the rami. (Plate 4.) About the eighth year the pubic and ischial rami are united by bone, the point of union being represented in the skiagram by a localized thickening of the rami. Any actual separation between the rami may be lost radiographically as early as the fifth year, but is generally obvious at that age.

The unossified portion of the acetabulum is seen in the skiagram as a gradually diminishing, nearly horizontal cleft separating the iliac portion of the acetabulum above from the pubic and ischial portions below ; it ceases to be apparent about the fourteenth year, at which time secondary centres (not demonstrated radiographically) appear in the Y-shaped cartilage of the acetabular floor.

The separation of the ischial from the pubic portion of the acetabulum is not apparent in the usual view of the pelvis after about the second or third year.

About the fifteenth year secondary centres appear for the crest of the ilium, the tuberosity of the ischium, the anterior inferior iliac spine and the symphysis pubis. The last two are not constant.

The epiphysis for the tuberosity of the ischium is not well seen

radiographically owing to its position on the posterior and inferior aspect of the ischium, but the other epiphyses are all readily demonstrated.

Centres are described as occurring with some frequency for the pubic and ischial spines, and crest of the pubis, but these are not usually observed in a skiagram.

Complete bony fusion of the epiphyses with the diaphyses takes place about the twentyfifth year, radiographic evidence of any division generally being lost about the eighteenth to the twentieth year.

Developmental variations and abnormalities of the os innominatum.—The upper lip of the acetabulum is sometimes formed from a secondary centre of ossification which may fuse with the underlying bone or may remain as a distinct separate ossicle throughout life. This ossicle, when present, is nearly always bilateral, a fact which is of value in excluding a fracture in this region.

Congenital dislocation of the hip appears to be due in many cases, if not in all, to a developmental defect of the acetabulum. Two primary acetabular abnormalities may be recognized in a skiagram (Plate 7, Fig. 1):

(1) A varying degree of deficiency in that portion of the acetabulum formed from the ilium. This is not very obvious as a rule at birth, or during the succeeding few months of infancy, owing to the cartilaginous condition of the acetabulum.

(2) An increased thickness of the acetabular floor, resulting in a flattening of the normal concavity for the head of the femur. This is also seen very much better as ossification extends into the parts involved.

Secondary changes in the region of the acetabulum are the result of weight-bearing, and consist of some degree of depression in the ilium above the acetabulum, representing false acetabulum-formation. This is generally obvious in adults, and may be seen within the first decade.

At birth the displacement of the femur is slight and is seen to be outwards as well as upwards. Increase of the upward displacement is comparatively slight until the commencement of weight-bearing. Development of the head and neck of the femur is retarded on the affected as compared with the sound side in unilateral cases, and the whole upper end of the femur remains somewhat smaller than normal in untreated cases. Anteversion of the head frequently produces an appearance of an unduly short, twisted, femoral neck, but this is more apparent than real.

In the early years of life, while ossification of the acetabulum is still incomplete, minor degrees of displacement are verified by the construction of " Shenton's line " : in the normal individual,

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continuation inwards of the curve formed by the under-aspect of the
neck of the femur will be found to blend without any angulation with
the continuation outwards of the curve formed by the upper margin
of the obturatory foramen.   Angular junction of these two curves
indicates either deformity of the upper end of the femur (e.g. some
form of coxa vara) or displacement of the femur upon the pelvis.

After manipulation of a congenital dislocation the patient is usually
sent for verification of the reduction with the limb in Lorenz's position
—i.e. the femur is flexed, abducted, and externally rotated.   In this
position Shenton's line is no longer available, and some other criterion
must be adopted.   It will be found that in complete reduction the
centre of the ossific nucleus in the femoral head lies opposite the clear
space in the acetabular floor which represents the upper limbs of the
Y-shaped cartilage.   (Plate 7, Fig. 2.)   Incomplete reduction will be
indicated by some variation in this relationship.

The Femur

The shaft of the femur ossifies from a single centre appearing very
early in fœtal life.

Secondary centres appear as follows :

One for the lower extremity, ninth month of fœtal life.
One for the head of the femur, about the end of the first year.
One for the great trochanter, fourth to fifth year.
One for the lesser trochanter, tenth to fourteenth year.

The three epiphyses of the upper extremity join the shaft about
the eighteenth year, the epiphysis of the lower extremity joining about
the twentieth year.

At birth the upper end of the femur in a skiagram appears merely
as a slight expansion of the shaft, with a convex upper border.   The
expansion is chiefly on the inner aspect of the bone, and represents an
extension of ossification from the shaft into the lower border of the
cartilaginous femoral neck.   The remainder of the neck of the femur
is entirely cartilaginous at this stage.   Ossification of the femoral neck
proceeds by continued extension upwards and inwards from the
shaft, and by the end of the third year the radiographic appearances
of the neck and head of the femur bear a considerable resemblance
to these parts as seen in the adult.   This resemblance is greatly in-
creased by the appearance of the ossific nucleus in the great trochanter
at the fourth or fifth year.   The upper aspect of the neck of the femur
is not, however, completely ossified until the end of the fifth year.
The method of ossification of the femoral neck appears to offer an
explanation of the deformity seen in the infantile type of coxa vara,
described in a later chapter, p. 45.   (Plate 4.)

The lower extremity of the femur is entirely epiphysial ; the in-

ferior aspect frequently shows considerable irregularity of outline in the early years of life, and it must be remembered that this irregularity is not articular, but represents the extension of ossification into the cartilaginous condyles.

Developmental abnormalities.—Congenital dislocation of the knee-joint is a very rare condition. The displacement of the tibia is generally forwards. It is not possible to differentiate congenital from traumatic dislocations by radiographic means alone.

The Patella

The knee-cap ossifies from a single centre which appears between the end of the third and the beginning of the sixth year. It is extensively ossified by the tenth year.

Developmental variations.—The lateral patellar borders are often formed by one or more separate ossicles. These are frequently bilateral but not necessarily symmetrical. Occasionally the patella ossifies from multiple minute nuclei, the skiagraphic appearance then resembling that of the trochlear portion of the lower humeral epiphysis. (Plate 7, Fig. 3.) The irregular multinucleated ossification may be obvious as late as the fourteenth year. The apex of the patella is frequently elongated, forming the " beaked patella." The extremity of the elongated apex not uncommonly ossifies from a separate centre, and may remain ununited throughout life. This condition when seen in the adult is often mistaken for fracture ; it is, indeed, indistinguishable radiographically from an old ununited fracture, but the presence of a continuous cortex around the opposing surfaces of the two bones quite definitely excludes a recent bony injury. Comparison of skiagrams of both patellæ will frequently be helpful in determining the developmental nature of the abnormality.

The Tibia and Fibula

The shafts of these bones are each ossified from a single centre, appearing early in fœtal life. The shafts are completely ossified at birth.

Epiphysial ossific nuclei appear as follows :

    One for the upper extremity of the tibia, just before birth.

    One for the lower extremity of the tibia, during the first year.

    One for the upper extremity of the fibula, during the fifth, or more often the sixth year.

    One for the lower extremity of the fibula, towards the end of the first year.

The head of the tibia is fairly extensively ossified by the seventh year. About the tenth year, or soon after, is seen an extension downwards of ossification into the tubercle on the anterior aspect of the

upper extremity. It is very common, however, to see small multiple ossific nuclei in the lower part of the tubercle, the upper part only being ossified by extension from the head. Sometimes the entire tubercle is ossified from one or more separate centres.

The lower epiphysis of the tibia is extensively ossified by the end of the fifth year, except for the internal malleolus, which is wholly cartilaginous at that age. Ossification is seen extending into the internal malleolus about the seventh year.

The position of the lower epiphysial cartilage of the fibula opposite the horizontal joint-space of the tibio-astragaloid articulation is noteworthy.

Developmental variations of the tibia and fibula.— A small separate ossicle is occasionally seen immediately below the tip of the internal malleolus.

THE TARSUS

Each of the tarsal bones develops from a single centre, except the os calcis, the posterior aspect of which is formed from a separate epiphysis. The ossific nuclei appear as follows :

One for the *os calcis*, at the sixth month of foetal life.

One or more for the *epiphysis of the os calcis ;* this is usually seen by the fifth year, and may be visible as early as the third year, but is sometimes delayed to the sixth or early part of the seventh year. It is usual to see two or more ossific nuclei in this epiphysis, and division into two portions is generally obvious until about the eleventh or twelfth year. The epiphysis is always more opaque in the skiagram than is the adjacent diaphysis, and the opposing surfaces show a varying degree of crenation. Minor differences on the two sides are common, and possess no clinical significance. Fusion of the epiphysis and diaphysis takes place about the eighteenth year.

One for the astragalus, at the seventh month of foetal life.

One for the cuboid, at the end of foetal life.

One for the external cuneiform, during the first year.

One for the internal cuneiform, early in the third year.

One for the middle cuneiform, somewhat later in the third year.

One for the scaphoid, in the third year. The ossific nucleus of the scaphoid may be quite large by the end of this year. Its appearance may, however, be delayed till the fifth or even the sixth year (*see* below).

Developmental variations and abnormalities of the tarsus.—Ossification from multiple nuclei is quite common in the scaphoid, and is not very uncommon in the internal cuneiform. A similar method of ossification is occasionally seen in the middle and external cuneiforms. The initial appearance of ossification in the

scaphoid is often delayed to the fifth or sixth year when multinuclea-
tion is present. Some evidence of this method of development is
apparent for about two years from the first appearance of ossification ;
after that time no distinction can be made between a scaphoid which
has ossified from several nuclei and one which has developed from
the more usual single centre. This subject is referred to again under
Köhler's Disease of the Scaphoid (p. 68), on which condition it has
an important bearing.

Accessory ossicles are common in the tarsus. The *os trigonum
tarsi* at the postero-external angle of the astragalus is frequently seen.
Sometimes there is a definite projecting tubercle at this part of the
astragalus without a separate ossicle. The *secondary os calcis* is rather
rare. It is a small ossicle lying in the angle between the os calcis,
astragalus and scaphoid, and is very apt to be mistaken for a fracture
of the supero-anterior border of the os calcis. The *secondary astragalus*
is a small ossicle lying on the upper aspect of the neck of the astragalus,
and is also rather rare, but the *astragalo-scaphoid* ossicle, lying between
the astragalus and scaphoid at their upper aspects, is quite common.
This ossicle usually appears to belong to the scaphoid, and is easily
mistaken for a fracture of the postero-superior margin of that bone.
The *os tibiale externum* lies proximal to the tubercle of the scaphoid.
Sometimes the tubercle is very prominent in one foot, while in the
other a separate ossicle is seen. An ossicle once formed, however,
does not fuse with the scaphoid but remains separate throughout life.
An *extra cuneiform* is sometimes, but very rarely, present. The sesa-
moid bone in the tendon of the peroneus longus does not appear till
early adult life. Numerous other accessory ossicles are described in
the tarsus, but cannot be demonstrated radiographically, and will not
therefore be enumerated here.

THE METATARSUS AND PHALANGES

Each of these bones develops from two centres, one.for the shaft
and one for an epiphysis. The centres for the shafts appear early
in fœtal life. Epiphysial centres appear as follows :

One for the base of the 1st metatarsal, in the third year.

One for the head of each of the other metatarsals, in the third
year.

One for the base of each phalanx in the 1st row, in the third year.

One for the base of each phalanx in the 2nd row, a little later
in the third year.

One for the base of each phalanx in the 3rd row, late in the fifth
year.

Fusion takes place between the epiphyses and diaphyses in the
seventeenth to the twentieth year.

The sesamoid bones beneath the head of the 1st metatarsal appear about the thirteenth year. They are extensively ossified by the fifteenth year.

Developmental variations and abnormalities of the metatarsus and phalanges.—Variations in ossification are exceedingly common in the metatarsus. An extra epiphysis is frequently seen for the head of the 1st metatarsal ; rarely an extra epiphysis appears for the base of the 2nd metatarsal. The heads of the outer four metatarsals often ossify from two distinct nuclei, which fuse about the sixth or seventh year. A small epiphysis is often seen on the extero-inferior aspect of the tubercle of the 5th metatarsal, and is frequently mistaken for the rare os Vesalii, described below. The epiphysis for the base of the 1st phalanx of the big toe is sometimes divided into two lateral halves, with a narrow intervening dorso-plantar cleft which remains cartilaginous until after the tenth year. Occasionally the bases of the other phalanges show multiple ossific nuclei.

The internal sesamoid bone, below the head of the first metatarsal, is frequently divided into an anterior and posterior portion, the division remaining throughout life.

Accessory ossicles.—The *intermetatarsal ossicle* is seen between the bases of the 1st and 2nd metatarsal bones. The *os Vesalii* is a large ossicle forming the proximal portion of the tubercle of the 5th metatarsal, and remaining separate throughout life.

Both these ossicles are *of rare occurrence.*

Ossification may be influenced by localized or remote lesions producing no other radiographic evidence of bony abnormality. The most common instance of this is the advanced ossification seen in Still's disease and allied periarticular inflammatory lesions ; the early appearance and rapid growth of ossific nuclei are best seen in these conditions in the carpus.

Retarded development of all bones may be present in hypothyroidism, and late fusion of the epiphyses of the long bones in hypogonadism ; while in cases of precocious puberty there may be advance in the development of the epiphyses with early fusion.*

Generalized early epiphysial fusion sometimes occurs in achondroplasia, but in this disease other and more characteristic skeletal changes are demonstrated.

* Engelbach and McMahon, " Radiology," 1924.

ABNORMALITIES OF BONES AND JOINTS

ABNORMALITIES OF BONES

THE changes which are seen in skiagrams of bone diseases are very diverse, and may be exceedingly complicated. To ensure a complete analysis and full appreciation of these changes it is necessary, therefore, to adopt a definite system in the examination of bone skiagrams. The analysis of abnormal appearances may be made under the following headings :—

    1. Abnormalities in size.
    2. Abnormalities in form.
    3. Abnormalities in structure.

    1. **Abnormalities in size.**—Abnormalities in size alone are frequently of developmental origin. They are also seen as the result of comparative or complete disuse, and of excessive use, especially where these factors have been operative during the years of growth.

    2. **Abnormalities in form.**—If without any other change, these abnormalities are also frequently of developmental origin. Seen in conjunction with structural changes, abnormalities of form are common in the majority of bone diseases.

    In general, it may be stated that abnormalities of size and form, occurring either singly or in combination, but without any structural change, are inconsistent with an acquired primary lesion of bone.

    3. **Abnormalities in structure** occur sooner or later in all acquired primary lesions of bone, in many developmental abnormalities, and in a number of other conditions in which the skeletal change is not primary but dependent on some remote lesion.

    On analysis, structural changes can be placed in the following categories :

    (a) *Simple disordered arrangement of lamellæ.*—This abnormality, occurring without other structural change, is most commonly seen in developmental malformations. (In combination with other structural change, irregularity of lamellar arrangement forms a prominent part in the skiagraphic appearances of many diseases.)

(b) *Destructive changes* $\left\{\begin{array}{l} \text{Rarefaction.} \\ \text{Loss of detail in bone structure.} \\ \text{Complete loss of bone-shadow.} \\ \text{Sequestrum-formation.} \end{array}\right.$

(c) *Reactionary changes* $\left\{\begin{array}{l} \text{Periostitis.} \\ \text{New-bone formation.} \\ \text{Sclerosis.} \end{array}\right.$

Site of origin.—In addition to the preceding analysis of structural changes, the site of origin of the lesion must, where possible, be determined. This may be (i) central, (ii) cortical, (iii) subperiosteal, or (iv), where an articulation is involved, subsynovial.

The site of origin of the disease is generally indicated by the greatest change in structure ; or by the area of maximum destruction where destructive and reactionary changes are combined. In recent inflammatory lesions and in neoplasms the site of origin can generally be determined without much difficulty. In inflammatory disease of long standing, the situation of the primary focus may not be very obvious ; widespread inflammatory change, however, involving the entire thickness of the bone, is generally indicative of a primary central infection.

DETAILED CONSIDERATION OF DESTRUCTIVE AND REACTIONARY CHANGES

It is of the utmost importance to realize at the outset that destructive and reactionary changes, as recognized in the skiagram, are indicative of the subtraction or addition of the opaque salts of bone, i.e. calcium phosphate, carbonate and fluoride, with a small proportion of magnesium phosphate. Hence it is possible for extensive disease to co-exist for an appreciable time with normal skiagraphic appearances. This is particularly common in acute infection of bone, in the early stages of which condition a negative X-ray examination is of no significance whatever.

It is unfortunately impossible to lay down any rule as to the time which may elapse before some abnormality can be noted in the skiagram, owing to great individual variation in this respect ; but a normal skiagram may certainly be seen a week after the onset of an acute bone-infection.

Rarefaction may be quite localized, or very widespread, and may be uniform over the whole of its extent, or exceedingly irregular. Rarefaction indicates increased translucency of bone to X-radiation, and careful examination will reveal that this increased translucency is due to one of two causes, or to both combined :

1. The lamellar structure is unaltered, but the individual lamellæ are abnormally translucent,
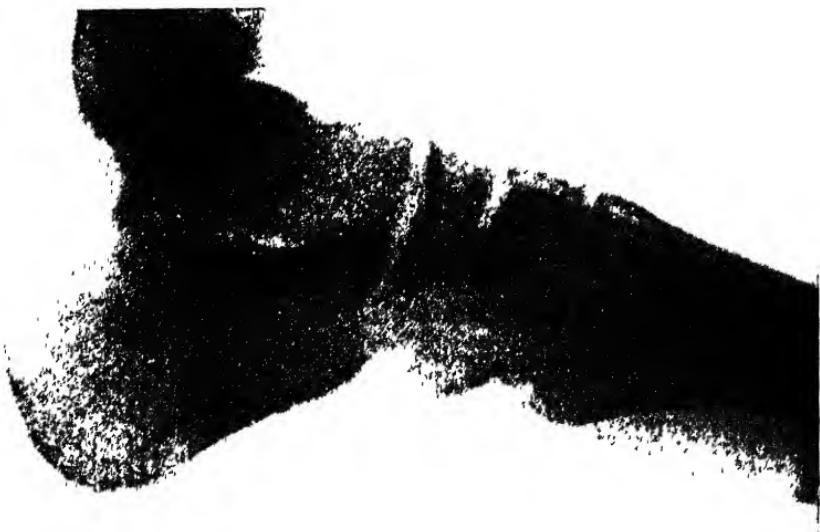
Fig. 1.—First or "mottled" stage of acute bone-atrophy of tarsus.

Fig. 2.—Second stage of acute bone-atrophy.

PLATE 8.

2. The *number* of lamellæ is diminished, resulting in increased size of the interlamellar spaces. In this variety of rarefaction (often spoken of as atrophy of bone) some of the remaining lamellæ may actually show increased thickness and density; if unaccompanied by other destructive change it generally indicates an old healed lesion, or a simple condition of disuse; it is also seen as a generalized change, more or less marked, in old age.

There is a peculiar type of rarefaction, forming a definite radiographic entity, which requires mention. This condition is known as acute bone-atrophy, and develops within a variable length of time—generally four to eight weeks—after the onset of some definite lesion of bone or of soft tissues. The atrophy is generally widespread, although the causative lesion may be quite localized.

Two distinct stages are seen in serial skiagrams of acute bone atrophy:

First stage.—The radiographic appearances are variously described as "mottled," "spotty," "dissolved." Numerous small areas of rarefaction are seen in the affected part, and the trabeculæ show a remarkable loss of detail, the whole bone structure appearing blurred and ill defined. It has been conclusively proved that the process is not infective, although it may result from an adjacent infection. The carpus and tarsus are particularly prone to undergo this change, and the extremities of long bones are affected earlier, and to a more marked degree, than the shafts. The length of duration of this stage of bone-atrophy is indeterminate, but it has been seen for upwards of a year after onset. Minor degrees of atrophy may undergo complete resolution, but generally the second stage is entered upon, and results in permanent abnormality. The pathology of the mottled condition is not known. (Plate 8, Fig. 1.)

Second stage.—This stage, known as *atrophie en masse*, gradually supervenes on the mottled stage. The affected bones show a perfectly regular rarefaction due to increased space between the lamellæ; some of the lamellæ are thinner than normal, a few may show increased density and thickness, as if they had undergone hypertrophy in compensation for the general increased fragility of the bone structure. In contradistinction to the first stage, the bone structure in the second stage is perfectly defined: no loss of detail is now present. (Plate 8, Fig. 2.)

If the disease has affected growing bones, this eccentric atrophy may be accompanied by a certain amount of concentric atrophy.

Once the second stage of acute bone-atrophy has been entered upon, the changes appear to persist throughout life, without, however, being progressive.

Causation of acute bone-atrophy.—Baastrup* stresses the importance

* *Acta Radiologica,* vol. ii., 1923.

of disuse, either partial or complete, as a causative factor in producing the disease, and has performed a number of experiments on animals with results confirmatory of his views.

It would appear, however, that some other factor is essential to the development of the atrophic changes. Acute bone-atrophy may supervene on an injury to bone, especially in the region of joints (Colles's fracture provides a not infrequent example) ; it may appear in inflammatory lesions of bone or of the soft tissues, in neoplasm of bone and in frost-bite. In inflammatory lesions of bone and neoplasm it may be impossible to demarcate the limits of the primary lesion from the surrounding atrophic changes.

The first, or mottled, stage of acute bone-atrophy is rarely seen in tuberculous lesions of bone, any atrophy noted in these lesions being usually typical of the second stage. This is an important point in the diagnosis of tuberculous from non-tuberculous inflammations of bones and joints.

It will be noted that the lesions which may be associated with acute bone-atrophy all necessitate some degree of disuse of the affected part.

Many theories have been advanced, in addition to that of simple disuse, to account for the condition. Most of these assume some disturbance of nerve supply—sympathetic, vaso-motor, trophic—but the pathology remains obscure.

The *diagnosis* of acute bone-atrophy from other atrophic conditions depends on the appearance of the characteristic mottled stage within a comparatively short time of the onset of some definite lesion involving, either directly or remotely, the part affected.

Loss of detail in bone structure.—This change most commonly results from irregular absorption of the opaque salts of bone, combined with more or less destruction of lamellæ ; in these instances loss of detail is accompanied by rarefaction, as in active inflammatory lesions and in the mottled stage of acute bone-atrophy. Loss of detail may also be produced by the irregular deposition of opaque salts, as may be seen in some chronic inflammatory lesions, or may result solely from a sclerosis so dense that all evidence of lamellar structure is obliterated. Complete loss of detail in a bony surface—e.g. the walls of an abscess cavity, or the subperiosteal surface of the cortex—is usually indicative of caries. (Plate 15.)

Complete loss of bone-shadow may indicate (1) destruction of bone by some inflammatory or neoplastic process ; or (2) formation between the bony lamellæ of some non-opaque tissue, without actual bone destruction. In the former instance there is definite solution of continuity of lamellar structure. In the latter, exemplified by some forms of diffuse osteitis fibrosa, the lamellar structure appears unin-

terrupted, but the trabeculæ are separated by clear spaces of varying size. This distinction may lack definite microscopic confirmation, but it is quite definite skiagraphically, and is of great value in radiographic interpretation. (Plate 17, Fig. 1, and Plate 37, facing p. 66.)

Sequestrum-formation.—Sequestrum-formation is frequently signalized by diffuse heavy deposit of opaque salts in the dead fragment. This is then seen in the skiagram as a very dense, more or less structureless opacity, separated in part or wholly from the surrounding bone by a zone of destruction. An unbroken zone of destruction around the whole circumference of the opacity is proof of complete separation of the sequestrum. Continuity of some part of the opacity with the surrounding bone indicates, on the other hand, that separation is incomplete. A deeply-placed sequestrum, even though it acquires this characteristic opacity of dead bone, may be completely obscured in the skiagram by dense sclerosis of the surrounding structure.

Sequestra do not always receive a deposit of opaque salts, but may appear as structureless shadows less opaque than normal bone. The diagnosis of sequestrum-formation can then only be made by the recognition of such a shadow surrounded by a zone of destruction in relation to bone which exhibits other evidence of inflammatory disease. It follows that while a positive diagnosis of sequestrum can generally be advanced with assurance, a negative diagnosis is far less conclusive, especially when the affected bone has undergone extensive structural changes as a result of longstanding inflammation. (Plate 17, Fig. 1.)

Periostitis in its early stages is not attended by any modification in the skiagram. Sooner or later, however, calcification takes place in the raised periosteum, and sometimes in the effusion between the periosteum and the cortex; or subperiosteal new bone is formed.

Calcification in raised periosteum alone produces a fine curved linear shadow, separated by a clear space from the cortex, and blending with the cortical shadow at either extremity. If calcification occurs in the subperiosteal effusion the clear space between periosteum and cortex is largely replaced by a structureless, fairly uniform opacity, which is, however, in recent cases separated from the cortical surface by a narrow translucent zone; this translucent zone is not seen in old inactive lesions. (Plate 15.)

Extensive periostitis is usually accompanied by subperiosteal new-bone- formation. This is generally laid down in successive layers, parallel with one another, more or less closely adjacent, and regular in structure. In acute staphylococcal infection of bone, producing extensive widespread changes, the orderly production of new bone described above is frequently absent; and in its place is substituted a diffuse, very irregular bone-proliferation of abnormal structure. (Plate 16.)

Occasionally, in subacute or chronic inflammatory lesions, subperiosteal bone is laid down in lamellæ radiating more or less vertically from the surface of the cortex. This condition bears some superficial resemblance to the radiating spicules seen in periosteal sarcoma. The lamellæ in inflammatory lesions are, however, much more robust in structure, more closely placed, and more opaque than the neoplastic spicules ; and characteristic inflammatory changes can generally be made out in the underlying bone.

New-bone formation presents many diverse appearances, according to its site and the nature of the primary lesion. The common varieties of subperiosteal new-bone formation have been noted above. New bone more deeply situated is generally rather irregular in lamellar structure, and in inflammatory lesions may show areas of sclerosis and rarefaction almost from the outset. Extensive new-bone formation of perfectly normal structure is occasionally seen around a small deep-seated inflammatory focus, generally of pyogenic origin. This condition is generally seen in growing bones, the inflammatory focus appearing to act simply as a stimulus to increased activity. Callus-formation around fractures appears first as a diffuse opacity, and only assumes a definite bony structure after a variable, but often considerable interval. Ossification sometimes occurs in tumours which have replaced normal bone, and is then generally exceedingly irregular. (Plate 18, and Plate 33, Fig. 1, facing p. 62.)

Sclerosis produces increased opacity in the skiagram. In very advanced sclerosis the opacity may be so dense that no bone structure is discoverable. Usually, however, it can be seen that the increased density is due to diminution of the interlamellar spaces, and to increase in thickness in the individual lamellæ. It is also obvious as a rule that the sclerosed lamellæ are the seat of abnormally heavy deposits of the opaque bone salts. Sclerosis often coexists with new-bone formation, and this new formation may then also exhibit sclerotic features.

Sclerosis is sometimes quite regular over the whole area involved, as in inflammatory lesions chronic from the outset, in which destructive changes have been inconsiderable.

Irregular sclerosis is typically seen as an end-result of acute staphylococcal infections, but is observed to a less extent in many other lesions. (Plate 16.)

In a certain number of lesions increased, irregular deposit of opaque salts appears to take place without reference to the existing bone structure, producing diffuse structureless opacities in bone. This condition is exemplified by Paget's disease, especially in the vault of the skull ; it must be differentiated from true sclerosis, which is a reparative process. (Plate 36, Fig. 2, facing p. 65.)

ABNORMALITIES OF JOINTS

In **lesions of the joints** the foregoing analysis must be made as regards the bones entering into the articulation. This analysis must then be augmented by the following observations :—

1. The **condition of the articular cartilages** must be determined in so far as is possible. Cartilage is normally quite translucent to X-radiation, but *calcification* produces recognizable density, seen in the skiagram either as scattered punctate opacities, or, if extensive, as a fairly uniform structureless opacity.

Erosion of the articular cartilages results in diminution of the joint-space normal to the age of the individual. Two difficulties are encountered in determining the presence of cartilage erosion—one, that the joint-space in early life is not demarcated by the limit of ossification in the articular extremities as in the adult ; the other, that even in the adult the joint-space (i.e. the depth of the cartilages) varies in the different articulations. It is obvious, therefore, that complete familiarity with the normal appearances of the different joints, at all ages from infancy to adult life, is essential for correct interpretation.

2. The **presence or absence of opaque bodies in the joint cavity** must be noted. " Loose bodies " in the joint are not necessarily opaque—they may be entirely cartilaginous; but a loose body which has been present for any considerable period of time is usually the seat of calcareous deposit, which renders possible its detection in the skiagram. It is of some importance to determine whether an intra-articular opacity is really a loose body, or representative of calcification or ossification in some anchored structure, such as a synovial fringe or incompletely detached fragment of cartilage. This point can often be cleared up by observing the range of mobility of the opacity in successive examinations.

3. The **tissues in the region of the joint-capsule** must be examined for **increased density, calcification or ossification.**

Increased density of the capsule, without calcareous or ossific deposit, is practically diagnostic of capsular tuberculosis ; it is advisable, however, to compare a skiagram of the affected joint with one of the sound side, obtained at the same examination and under precisely similar conditions. Only in this way can a just estimate be formed of the presence and extent of capsular thickening.

Calcification and *ossification* in the capsule and adjacent ligaments, generally in the neighbourhood of the bony attachments, and comparatively slight in amount, frequently occur as a result of trauma. Extensive capsular ossification is occasionally seen resulting from trauma, and is frequently a prominent feature in the neuro-arthropathies, i.e. Charcot's disease and the arthropathy of syringomyelia.

ABNORMALITIES OF BONES AND JOINTS (*continued*)

ABNORMALITIES of the skeletal system may be classified for descriptive purposes as follows :
  1. Developmental abnormalities.
  2. Static deformities.
  3. Traumatic lesions.
  4. Inflammatory lesions.
  5. Neoplasms.
  6. Parasitic diseases.
  7. Diseases of unknown or doubtful pathology.

1. DEVELOPMENTAL ABNORMALITIES

The developmental abnormalities special to the various parts of the skeletal system have been already described in connexion with regional ossification (*see* Chapter II). Developmental abnormalities which may affect any part of the skeleton include defective growth, complete absence of part or whole of one or more bones, local gigantism, reduplication.

Analysis of the radiographic appearances of the bones in all developmental abnormalities, apart from actual loss or reduplication of some skeletal element, may reveal abnormality in size, in form, and in arrangement of lamellæ, either singly or in combination. There is complete absence of any destructive or reactionary change. (Plate 5, Figs. 1, 2, 3.)

Multiple developmental abnormalities conforming to no recognized type of lesion are not infrequently encountered. These conditions vary widely in general appearance, but on analysis are all found to exhibit the features characteristic of a developmental disorder.

The following generalized developmental diseases affecting the skeletal system are productive of typical changes in the skiagram which do not conform to the rules given above for developmental abnormalities :—

Osteogenesis imperfecta.—This condition is characterized by the occurrence of multiple fractures, both intra-uterine and post-natal, the liability to fracture gradually diminishing, as a rule, with

Fig. 1.—Osteogenesis imperfecta.

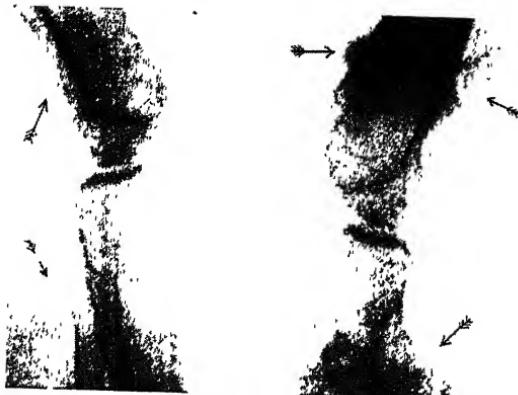Fig. 2.—Achondroplasia in an inf.

Fig. 3.—Static scoliosis.

Fig. 4.—Diaphysial aclasis.

PLATE 9.

the passage of the first few years of life. The most striking feature of the skiagram in infancy is the presence of multiple fractures of the long bones, many of which have united with extreme deformity and excess of callus. Apart from these deformities and callus-formations the bones appear to have been originally of normal size and form. There is a very marked rarefaction, usually fairly regular, due to generalized decalcification, although the callus around the fractures, which unite rapidly, shows normal opacity. The lamellæ of the cancellous tissue are poorly defined owing to the general rarefaction, the cortex is abnormally thin, and the medullary canal is wide. The epiphysial cartilages are narrow, but show no irregularity.[*] In later life the radiographic changes are those of general atrophy, both concentric and eccentric, with narrow cortex, and widely spaced lamellæ in the cancellous tissue. Definition is, however, perfect as regards structure throughout the skeleton. The deformities result- . ing from malunion of fractures of course persist, but the site of these fractures is no longer marked by exuberant bone-formation, the excess of callus having been absorbed. Bony union appears to be complete, although it is by no means uncommon for refracture to take place through the line of an old lesion. (Plate 9, Fig. 1.) It will be noted that the radiographic appearances in this disease differ from those ascribed to developmental abnormalities in general, destructive and reactionary changes both being present.

Achondroplasia.—This disorder of ossification affects chiefly those parts which are still entirely cartilaginous at the sixth month of intra-uterine life, although all bones developed in cartilage appear to be involved to some extent. In infancy the radiographic diagnosis is by no means easy, and in many instances may be impossible. In a typical example, however, it will be seen that the epiphysial surfaces of the diaphyses of the long bones present an unduly dense structure, while the margins of these surfaces may show small bony projections from the cortex. The shafts of the long bones may appear somewhat broader and shorter than usual, but this is rarely a conspicuous feature. (Plate 9, Fig. 2.)

In later childhood the skiagram provides much more definite evidence of the disease. Epiphysial ossification occurs early, and fusion with the diaphyses is often complete in the long bones by the age of 12–15. If examined before fusion takes place, it will be found that the epiphysial cartilage is unduly narrow though quite regular. The condensation of the epiphysial surface of the epiphyses noted above is by no means constantly observed, but broadening of the diaphysial extremities due to subperiosteal proliferation is generally present. Proliferation also tends to occur in the cortex and subcortical can-

* Locke, " Diseases of Bones," 1921.

cellous bone at points remote from the epiphyses, producing abnormalities in the form of the shafts. This is especially common in the radius and ulna. Synostosis is said to occur early at the base of the skull, but this cannot be demonstrated with certainty in the skiagram.

Various deformities other than those mentioned above are generally seen in late childhood and adult life : the vertebral bodies, although affected but slightly, in consequence of their early ossification, show some degree of compression with irregularity of the articular surfaces ; the ribs lie in a plane tending to the horizontal, and the normal curvature of the clavicles is diminished. The outlet of the pelvis is diminished and the obturator foramina are enlarged. The carpal bones are often small, the metacarpals short and broad, with divergence of the ring and middle fingers, producing the characteristic " spade " or " trident " hand.* The phalanges do not as a rule show much change, but may be rather short and broad.

Dyschondroplasia (Ollier's disease).—In this rare condition the diaphysial extremities of the long bones show marked structural changes while remaining normal in shape and size. The lamellæ of the cancellous tissue form distinct bundles, spreading out in a fan-like manner as the epiphysis is approached. The lamellæ themselves are of normal structural appearance. Between the bundles of lamellæ are areas of complete loss of bone-shadow, this being unaccompanied by any loss of continuity in the intervening lamellæ—i.e. the appearances are characteristic of replacement of bone by some non-opaque substance, not of erosion. The non-opaque tissue is, in fact, cartilage. The pathology of the disease is unknown, but Bentzon† suggests that the disorder is neurotrophic, the result of abnormal innervation of the nutrient arteries. The pattern produced by the cartilaginous striæ certainly conforms closely to the divisions of these vessels.

Diaphysial aclasis is characterized by the formation of multiple osteomata, by deformities of the diaphysial extremities of the long bones in general, and by a characteristic deformity of the bones of the forearm. (Plate 9, Fig. 4.) There is a strong tendency to hereditary transmission of the disease.

The clinical manifestations (i.e. the occurrence of multiple swellings in connexion with the long bones) make their appearance at varying ages, usually about the third or fourth year.

Radiographic examination reveals multiple abnormalities in size and form of the long bones, especially of the diaphysial extremities, with irregular lamellar arrangement. A diaphysial extremity typically

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* Lewin and Jenkinson, *Amer. Journ. of Roent.*, 1924.

† *Acta Radiologica*, vol. iii., fasc. 2–3.

shows increase in circumference, slight irregularity in outline, and irregular spacing of cancellous lamellæ without loss of lamellar structure—i.e. there are the structural appearances of replacement of bone by some non-opaque substance. This spacing of lamellæ is quite irregular and is thus strikingly dissimilar from the diaphysial appearances of Ollier's disease noted above.

In addition to these changes, the form of the long bones is greatly modified by the presence of multiple bony outgrowths. These possess the radiographic characteristics of osteomata ; that is, they are seen to consist of cancellous bone of irregular lamellar arrangement, covered by a thin cortical layer, both cancellous tissue and cortex being directly continuous with the corresponding structure of the parent shaft.

The osteomata are sessile, and even may appear not as outgrowths from but as deformities of the original shaft, an exaggeration of the common diaphysial deformity described above.

There is generally a considerable symmetrical resemblance in the deformities, and outgrowths of corresponding bones on the two sides of the body.

The forearm bones often present characteristic abnormalities. The lower extremity of the ulna shows the changes described above as common to diaphysial extremities, but in addition is deficient in length, stopping short of the lower radial extremity by a considerable interval ; while at the elbow-joint the head of the radius is displaced outwards, being separated by an abnormally wide space from the upper end of the ulna.

These deformities of the forearm are not invariably seen in diaphysial aclasis ; when present they are generally roughly symmetrical.

2. STATIC DEFORMITIES

Static deformities of bone are characterized by abnormalities in form, and to a less extent in size ; in longstanding cases there may also be noted some modification in arrangement of lamellæ, this rearrangement being obviously designed to fit the bone for the mechanical conditions imposed upon it by the deformity. Destructive and reactionary changes are entirely absent. Static and developmental abnormalities as seen in the skiagram may therefore be indistinguishable. Clinically, however, this difficulty rarely arises, and the radiologist's task is to differentiate a static deformity from one due to disease of bone. The absence of destructive or reactionary changes in the bones involved, or of cartilaginous erosion in adjoining articulations, enables primary disease of bones or joints to be excluded with confidence.

Generally speaking, static deformities of bone are found to be

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less extensive than the clinical examination would suggest, and in early cases no bony abnormality whatever may be demonstrated, i.e. the bones have undergone no adaptive changes in size, form, or lamellar arrangement ; while the normal relationship of the bones to one another may be completely restored at the time of the examination, either by a voluntary effort on the part of the patient or, as is more usual, by the assumption of the horizontal position. In investigating early static deformities, therefore, it is sometimes useful to obtain skiagrams with the patient in the upright posture.

In **static scoliosis** the earliest radiographic abnormality noted is a rotation of the vertebral bodies in the affected segment of the spine, with some degree of curvature extending over the same area. At a later stage wedge-shaped deformity of the vertebral bodies is seen, with increased rotation. The rotation is best estimated by the deviation of the spinous processes from the mid-line towards the convexity of the curve. Secondary curves, above and below the primary curve, are developed fairly early. Their direction is opposite to that of the primary deformity. For the examination of very early cases, where no abnormality is demonstrated, Lamb* suggests that antero-posterior skiagrams should be taken in the right and left scoliotic positions ; an increased curvature to one side indicates an early scoliosis, while symmetrical curvatures in the two skiagrams is good evidence that no scoliosis is present. (Plate 9, Fig. 3.)

Paralytic scoliosis can be differentiated from true static scoliosis by the absence of rotation of the vertebral bodies, and the absence also of any secondary curvatures.

Static kyphosis of the dorsal spine is often accompanied by a slight degree of scoliosis. Wedging of the vertebral bodies occurs owing to compression of the anterior portions of these structures. Secondary curvatures in the true sense of the term are not seen, but the normal cervical and lumbar convexities become exaggerated. Osteo-arthritic changes are almost invariable in longstanding cases of kyphosis. A severe, rapidly progressive type of dorsal kyphosis which occurs at adolescence is described under Abnormalities of Unknown Pathology, since it is certainly not primarily of static origin.

Static genu valgum and **genu varum** generally illustrate in a rather striking degree the common discrepancy between the clinical and radiographic features in this type of lesion—the skiagram often showing a deformity much less obvious than clinical examination would suggest. The deformity is found to consist of diaphysial overgrowth on the inner or outer sides of the femur or tibia, or of both these bones. The epiphysial cartilages are of normal width,

* *Amer. Journ. of Roent.*, 1922.

and the epiphyses themselves do not usually share in the asymmetrical development.

Static pes planus is indistinguishable in the skiagram in its early stages, unless the foot is examined while bearing the patient's weight—not an easy procedure. Later, when relief from weight is no longer followed by spontaneous reposition of the normal condition, a lateral skiagram will reveal some degree of displacement downwards of the head of the astragalus, accompanied by a general flattening of the longitudinal arch.

Loss of the transverse metatarsal arch is indicated in the dorsoplantar skiagram by abnormal separation of the distal portions of the metatarsal bones.

In **hallux valgus** the displacement outwards of the first phalanx upon the metatarsal is accompanied by a corresponding displacement of the sesamoid bones in the short flexor tendon. The external sesamoid may be seen below the 1st interosseous space in advanced deformities of this type. Secondary osteo-arthritic changes may occur in the 1st metatarso-phalangeal joint, but it is noteworthy that the more extreme deformities are often remarkably free from evidence of arthritis.

3. TRAUMATIC LESIONS

Minor traumata, either isolated, repeated, or constant over a long period, are productive of a number of clinical and radiographic entities, many of which are restricted in their incidence to certain regions of the skeletal system.

Traumatic periostitis is only demonstrated with any frequency in the tibia, although other bones possessing superficial surfaces may occasionally show the characteristic radiographic appearances. It is typical of this lesion that weeks or months commonly elapse between the original trauma and the occurrence of recognizable changes in the skiagram; while many cases obviously undergo complete resolution without these changes ever taking place. In a well-marked instance a dense, structureless node is seen on the surface of the cortex, with which it blends imperceptibly. In very old cases this opacity, which is due in the first instance to a calcification of a subperiosteal effusion, presents the structure of dense cortical bone, and appears as a smooth, bony projection from the cortex. Traumatic periostitis as seen in the skiagram is always exceedingly localized in extent, and is unaccompanied by any destructive changes in the absence of a superadded infection.

Epiphysial strain, resulting from a single trauma insufficient to produce any recognizable displacement, is most common at the lower end of the humerus. No abnormality is seen in the skiagram

for some weeks after the injury; a little new-bone formation then appears at the margins of the diaphysis or epiphysis, or both, often showing extension into the ligaments. Some degree of deformity of the epiphysis not uncommonly results in young subjects.

Schlatter's disease appears to be a traumatic epiphysitis of the tubercle of the tibia, produced by a single strain, or by repeated irritation from muscular traction. The characteristic abnormality seen in the skiagram consists in an irregular opacity in the soft tissues on the anterior aspect of the tibial tubercle, with some rarefaction and loss of detail in the tubercle itself. Later, this opacity in the soft tissues, originally structureless, presents the structure of cancellous bone, which may fuse with the tubercle, or persist throughout life as one or more nodules in the soft tissues. The statement formerly made, that Schlatter's disease occurs only where the tibial tubercle is ossifying from a separate centre, possesses no foundation in fact.

Actual elevation of the tubercle from the shaft, amounting to a partial epiphysial separation, is very rare in Schlatter's disease, as is also actual fragmentation of the tubercle. The great variations which normally occur in the ossification of this part render it essential that comparison be made with the sound knee before suggesting any actual displacement or abnormal fragmentation. (Plate 10, Fig. 1.)

Traumatic epiphysitis of the os calcis sometimes occurs in young children from the repeated muscular traction. The ossific nucleus of the epiphysis becomes increased in size, and structural detail is blurred, apparently as the result of irregular calcareous deposit. Irregularity of the opposing epiphysial and diaphysial surfaces, and multiplication of ossific nuclei in the epiphysis, are *not* evidence of irritation, but are perfectly normal appearances, in spite of statements to the contrary. In the vast majority of cases showing the clinical features of this lesion no radiographic abnormality is seen.

Irritation of the os tibiale externum (Plate 10, Fig. 2), when that bone is present, may result from pressure or traction. The ossicle shows increase in size and loss of detail in bony structure due to irregular calcification. The general opacity of the bone is increased, but small irregular areas of comparative rarefaction may be seen.

The **internal sesamoid** bone below the 1st metatarsal sometimes shows similar irritative changes—i.e. the bone is enlarged, detail is lost, and definite fragmentation of the ossific nucleus occurs; in this connexion the not uncommon normal division of the internal sesamoid into two portions must not be forgotten. The anterior aspect of the **patella** in children is occasionally affected in a similar manner. Renander* describes an excised sesamoid showing

* *Acta Radiologica*, vol. iii.

Fig. 1.—Schlatter's disease of tibial tubercle.   Fig. 2.—Bilateral os tibiale externum (unilateral irritation).

Fig. 3.—Osteo-chondritis desiccans of internal femoral condyle.

Fig. 4.—Osteo-chondritis desiccans of capitellum.   Old fracture of head of radius.

PLATE 10.

these changes, and states that much of the bone is necrotic, including the marrow.

Osteo-chondritis desiccans.—This lesion is confined to the inferior aspect of the internal femoral condyle and the inferior aspect of the capitellum of the humerus. It apparently consists in separation of a small portion of the articular surface of the bone by means of a zone of necrosis resulting from minor trauma, either single or repeated. The separated fragment is at first retained in position by the overlying cartilage, but later the cartilage is destroyed and the fragment of bone becomes a loose body in the joint. In the earlier stages, while the fragment is retained in position, the skiagram shows a narrow zone of destruction separating a small portion of the articular surface. Later, the fragment may be seen in any part of the elbow-joint where this articulation is affected. The fragment still retains its compact cortical surface with more or less cancellous tissue. The defect in the femoral condyle, or humeral capitellum, retains its original size for a time, but later becomes somewhat flattened, and a thin layer of compact bone is formed on the exposed surface of the cancellous tissue. The loose fragment eventually may also undergo changes in size and structure, and in the elbow, at any rate, may disappear, deformity of the internal aspect of the capitellum remaining as the sole radiographic evidence of the old lesion. (Plate 10, Figs. 3,4.)

Myositis ossificans traumatica may result from a fracture, but quite often supervenes on some comparatively trivial injury. The lesion may affect any muscle having direct attachment to bone by muscular fibres, but is most commonly seen in the brachialis anticus and the crureus. It does not often occur after early adult life.

A skiagram taken immediately after the injury will reveal no abnormality, unless a fracture has occurred. Within a few days, or a week or two, a diffuse structureless opacity is seen in the affected muscle, separated by a definite interval from the underlying shaft. This structureless opacity is gradually replaced by the appearance of a plaque of cancellous bone, the long axis and general lamellar arrangement of which are parallel to the long axis of the shaft, from which it is still separated by a definite interval. The demonstration of definite bony detail throughout the whole of the plaque is an indication of comparative inactivity of the lesion, but does not preclude the possibility of recurrence after operative removal. The new-bone formation usually shows gradual diminution in size once complete cancellous structure has been assumed, and may be completely absorbed. In very old cases a small node of traumatic periostitis may be seen on the shaft, indicating the site of the original injury. Traumatic myositis ossificans is very commonly seen in the brachialis anticus of young children, following a juxta-epiphysial fracture of the

humerus ; the crureus is more often affected in older children and young adults as the result of a blow on the thigh.   The new-bone formation in young subjects is often very extensive.   (Plate 11, Fig. 1.)

FRACTURES

Fractures can be diagnosed or excluded by radiographic means with absolute certainty, provided that skiagrams of first-class quality, and in two planes at right angles, are obtainable.   In some regions these essential requirements cannot be fulfilled, and the value of the radiographic method diminishes in direct ratio with the limitations thus imposed ; at other times a region presenting no anatomical difficulties is rendered more or less inaccessible for radiographic purposes as a result of splinting, restlessness of the patient, etc.

Screen examination as a means of diagnosis in fractures or any other bone lesion is absolutely useless.   A gross lesion of a large and superficial bone may be quite invisible on the fluoroscope, while, even if the presence of the lesion is determined, essential details will in many cases be missed.   In the same way, the most perfect skiagrams in one plane may fail to give any indication of an extensive bone injury. Should the examination, therefore, fall unavoidably short of the standard necessary for finality of diagnosis, the restricted value of the findings must be frankly recognized and definitely stated.

Fractures confined to the base of the skull can rarely be recognized, and never excluded.   Fractures of the lateral portions of the ribs, and of the posterior aspect of the sacrum, may also escape recognition, especially in fat subjects.

A **complete fracture** characteristically presents in the skiagram a loss of continuity in structure extending across the whole extent of the bone in both planes.   In one or both views this may be quite obvious, owing to separation of the fragments, but in other instances where no displacement has occurred, or impaction has taken place, very careful examination of the bone structure, both cancellous and cortical, may be necessary for diagnosis, while, as noted above, one view may provide no evidence of the lesion at all.   Impaction can usually be recognized from the projection of some portion of one fragment into the opposing surface of the other, but radiographic and clinical evidence as regards impaction are not always in accordance.

Incomplete fractures are diagnosed by uninterrupted continuity of structure between some portion of the fragments.   Three types of incomplete fracture can be recognized :—

(1) A *simple fissure*, without displacement, which does not extend through the whole thickness of the bone.

(2) A *greenstick fracture*, with angular deformity, the bony structure being uninterrupted across the concave aspect.

Fig. 1.—Traumatic myositis.
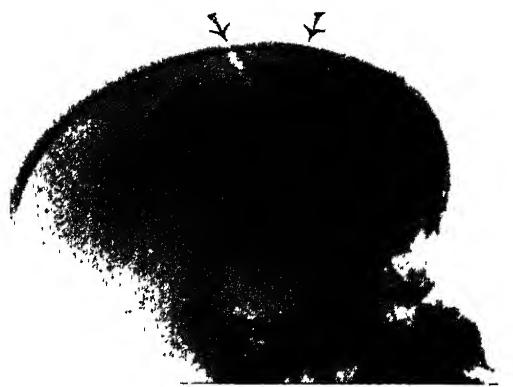

Fig. 2.—Crush fracture of radius.

Fig. 3.—Fracture of skull.

Fig. 4.—Fracture of surgical neck of humerus.

Fig. 5.—Intracapsular fracture of neck of fem

PLATE 11.

Fig. 1.—Fracture of scaphoid of carpus.

Fig. 2.—Fracture of scaphoid of tarsus with displacement of fragments.

Fig. 3.—Fracture of lower end of diaphysis of humerus.

Fig. 4.—Dislocation of semilunar bone.

Fig. 5.—Dislocation of shoulder with small fracture

PLATE 12.

(3) A *compression fracture*, which is very common in the lower end of the radius in young children, resembles an impacted fracture ; cancellous lamellæ and cortex, however, are seen to be mainly intact, but distorted, forming a projection, or bulging around the whole or part of the circumference of the shaft. (Plate 11, Fig. 2.)

In **comminuted fractures** the extent of the injury is generally apparent, but special care must be exercised in the neighbourhood of joints to determine involvement of articular surfaces.

Compound fracture cannot usually be differentiated from simple lesions in the skiagram, but the presence of air (seen as circumscribed translucent areas) in the soft tissues surrounding the fragments is strongly suggestive of a compound injury.

Fractures of the various types described above are illustrated in Plates 11, 12.

A complete regional description of fractures is unnecessary, but the following merit special mention on account of difficulty of recognition or of prognostic importance :—

Compression fracture of a vertebral body in the lower dorsal or upper lumbar region is a comparatively common injury, resulting from forcible excessive flexion of the spine. Unlike the majority of spinal injuries, the immediate symptoms are not very severe, and the patient is rarely sent for radiographic examination until some time has elapsed since the accident. Partly on account of this, and partly because of the anatomical situation, sufficient detail is not usually obtained in the skiagram to enable the actual line of fracture to be made out. In the lateral view the vertebral body affected is seen to form a truncated wedge, the narrow end being in front. Some slight irregularity of structure may be seen, but often the deformity alone is demonstrable. There is no destruction of bone, and the intervertebral disc on either side of the affected body retains its normal width, these two observations differentiating the lesion from neoplasm or caries.

In the antero-posterior view the deformity of the vertebral body may not be obvious, and the discs above and below may appear narrowed ; the lateral view is essential, therefore, for a correct diagnosis.

New-bone formations extending into the ligaments around the affected vertebra are common in cases of long standing, but ossification does not spread into the intervertebral discs. (Plate 13, Fig. 1.)

Fracture of the greater tuberosity of the humerus is of importance in that it frequently complicates a dislocation of the shoulder-joint, but it cannot usually be demonstrated after reduction of the dislocation when the limb is bandaged to the chest. External rotation of the humerus is necessary to bring the greater tuberosity into profile and so render the fracture visible.

Fracture of the head of the radius is the most common injury in the region of the elbow-joint in adults. The usual lesion is a vertical fissure passing down from the articular surface of the head and separating a small antero-external fragment. This fragment may show slight impaction, or be held in almost perfect position by the orbicular ligament; and in these cases, which form the majority, very careful examination of the skiagram is necessary to determine the injury. The lateral view will reveal a small break in continuity of the anterior cortical layer at the junction of the head and neck, and the fissure can then be traced upwards from this point to the articular surface. (Plate 13, Fig. 2.) Occasionally the small antero-external fragment is considerably displaced.

Fracture of the carpal scaphoid.—No radiographic examination of the wrist is complete which does not include the whole of the carpus. Fracture of the scaphoid is much the most common carpal injury, and takes place through the transverse axis of the bone at its narrowest part, just distal to the outer margin of the radial articular facet. The injury is best seen in the antero-posterior skiagram, and may not be very obvious, as displacement is generally slight. Failure to obtain an accurate antero-posterior view of the carpus results in foreshortening of the shadow of the scaphoid, which may prove very misleading, either by simulating deformity which is in fact non-existent, or by concealing a fissured fracture without displacement. It has been stated that bony union never occurs in fracture of the scaphoid; it is certainly very unusual. (Plate 12, Fig. 1.)

Fracture of the neck of the femur, with impaction but no other displacement, may be exceedingly difficult to recognize in very fat subjects. The line of cleavage may be quite invisible, and the only abnormality recognized in the skiagram may be a shortening of the femoral neck. This appearance is exactly simulated by a skiagram of the hip-joint with the femur in slight external rotation, and every care must therefore be taken to assure a vertical position of the inner border of the foot at the time of examination. (Plate 11, Fig. 5.)

Fracture of the spine of the tibia, or of a small portion of it, is not very uncommon. In cases seen immediately after the injury, displacement of the small fragment is often absent, a small fissure which may readily be overlooked forming the only radiographic abnormality. Careful examination of the tibial spine must therefore be made in all cases of suspected injury about the knee-joint. (Plate 13, Fig. 3.)

Fracture of the posterior margin of the lower end of the tibia rarely occurs alone, but is very common in conjunction with fractures of one or both malleoli. It is seen only in the lateral

Fig. 1.—Compression fracture of first
lumbar vertebra.

Fig. 2.—Fracture of head of radius.

Fig. 3.—Fracture of spine of tibia.

Fig. 4.—Fracture of os calcis.

Fig. 5.—Non-union of fra
humerus and false-joint f
tion.

PLATE 13.

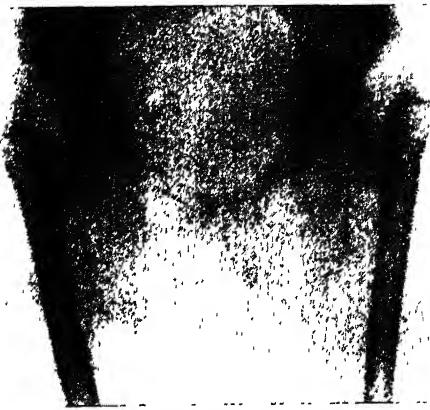Fig. 1.—Adolescent coxa vara.

Fig. 2.—Infantile coxa vara.

Fig. 3.—Dislocation upwards of outer end of clavicle.

Fig. 4.—Fracture - dislocation of ankle - joint.
Note fragment detached from posterior aspect
of tibia.

PLATE 14.

view, and may readily be mistaken for an oblique fracture of the lower end of the fibula. This fracture possesses a special importance of its own apart from the other injuries with which it is usually associated, in that it allows of minor backward displacements of the astragalus and may thus cause severe disability. The small posterior tibial fragment is generally displaced slightly upwards. (Plate 14, Fig. 4.)

Fracture of the os calcis.—No examination of the ankle-joint is complete unless the whole of the astragalus and the os calcis are included in the lateral view. Fracture of the os calcis is much the most common tarsal injury, and it is unfortunate that no satisfactory view at right angles to the lateral plane is obtainable. Fractures are generally impacted, and often extensively comminuted. The most common type consists of a comminuted impacted fracture of the anterior two-thirds of the bone, the main line of cleavage following an oblique plane downwards and forwards. In recent cases the actual fissures can be made out fairly readily; but in old cases, where bony consolidation has occurred, a diminution in vertical depth of the bone with some irregularity of lamellar arrangement often constitutes the only radiographic evidence of the lesion. Comparison with the sound foot is often advisable in these circumstances. (Plate 13, Fig. 4.)

Subperiosteal fracture of the metatarsals.—Spontaneous subperiosteal fracture of the second metatarsal is not very uncommon. The fracture usually occurs in the middle third of the shaft, is transverse in direction, unaccompanied by any displacement, and may almost defy detection. The lesion most often occurs in the course of a long march, and produces no symptoms until some hours have elapsed. If seen at this time the transverse fissure can generally be made out, inconspicuous as is the abnormality. The patient more often comes for examination several days later; a small spindle-shaped structureless opacity is then seen surrounding the shaft for a length of about half an inch. The fissure is situated opposite the maximum width of the opacity, but may be obscured by it. The opacity is due to deposition of opaque salts in a subperiosteal effusion of blood. Most of this is gradually absorbed, and only a small area surrounding the cortex eventually assumes the structure of sub-periosteal new bone.

Occasionally a fracture of this nature occurs in the third metatarsal.

Fracture of the 1st metatarsal sesamoid.—The internal sesamoid below the head of the 1st metatarsal is occasionally fractured. Radiographically the importance of this injury lies in differentiating a fracture from a normal sesamoid consisting of two ossific nuclei, the latter condition being quite common. Diagnosis of a fracture is made from the absence of a cortical layer on the opposing surfaces of the two

fragments. Where the sesamoid possesses two distinct nuclei, a thin but complete layer of compact bone is seen to surround each.

Spontaneous Fractures

These fractures occur as a result of practically any of the diseases of bone described later. They are particularly common in malignant neoplasms, and in benign central growths (e.g. enchondroma). The diagnosis of spontaneous fracture depends on recognition of the bony abnormality produced by the primary lesion.

Fractures also tend to occur as a result of trivial traumata in the aged and the insane. In the former, generalized atrophy is often present, but in the latter no apparent change may be seen to explain the liability to bony injury. The spontaneous fracture of the 2nd metatarsal described above is an isolated lesion the underlying pathology of which is quite unknown.

Bony Union of Fractures

Bony union of fractures generally takes place with a rapidity which is in inverse ratio to the age of the patient. Callus-formation is also normally much more profuse in infancy and early childhood than in adult life. Apart from these differences in degree, the following description is applicable to the normal repair of any fracture :

A skiagram of a recent fracture shows a simple loss of continuity, without any alteration in bone structure.

Within a comparatively short time—usually a few days—definite alteration in structure can be made out. This consists of loss of detail in the ends of the fragments, extending for a variable depth, but not usually for more than half to three-quarters of an inch, and most marked on the actual fractured surfaces. This loss of detail is due to irregular absorption of opaque salts, and a little later to actual absorption of a certain number of lamellæ. In adults this destructive change is generally apparent for some time before any reaction can be made out, but in young children it may be concealed by the rapid and excessive formation of early callus.

This structural alteration persists until bony union is well advanced.

After a variable interval a subperiosteal opacity is seen around the ends of the fragments, at first structureless, but soon presenting the appearance of subperiosteal bone laid down in layers parallel to the cortex. Each fragment thus becomes enlarged by a layer of subperiosteal bone, but extension of these layers to effect a junction between the fragments does not take place until later. In the meantime the destructive changes in the ends of the fragments become modified as the result of irregular calcification in and between the fractured surfaces. The formation of any actual new bone between

the opposing surfaces can rarely be detected until definite bony union has been effected by extension and junction of the subperiosteal layers described above. Eventually complete continuity is re-established in both cortical and cancellous structure. Much of the subperiosteal new bone is absorbed, and the remainder becomes blended with the cortex. The original line of cleavage is often marked by a narrow zone of condensation extending through the cancellous tissue.

Where gross displacement of fragments persists, the above description must of course be modified as regards the radiographic appearances in the later stages. The description of the earlier changes, however, holds good for all fractures which are undergoing normal repair.

It must be most strongly emphasized that bony union cannot be diagnosed from a skiagram until actual continuity of bone structure is seen between some portion of the fragments; and it is of equal importance to realize that this radiographic evidence may not be obtained until long after firm union is apparent on clinical examination. Manipulation under screen examination as a means of determining the presence of union is of no practical value whatever.

Delayed union is signalized by the late appearance of new-bone formation and its scanty amount. Subperiosteal bone-formation is very slight, extends slowly across the gap between the fragments, and is more dense in structure than is normal at this stage of repair.

A narrow, isolated bridge of subperiosteal bone often forms between the fragments, and is not followed by any general extension of continuity for long periods; the opposing surfaces of the fragments, however, retain the ill-defined structure noted above, which can be taken as definite evidence of some degree of activity in repair. Should the opposing surfaces resume their original clearly-defined cancellous structure, complete bony union is unlikely; while the appearance of a layer of compact bone extending over these surfaces from the cortex is conclusive of cessation of the reparative process.

Non-union of fractures.—Definite non-union can be diagnosed when, in the absence of any continuity between the fragments by subperiosteal bridges, the opposing surfaces of the fragments show a superficial compact layer of bone continuous with the cortex.

At a later stage, atrophy both concentric and eccentric takes place, unless the ends of the fragments are in contact, when one or both of the opposing surfaces often become considerably enlarged as a result of subperiosteal bone proliferation, and densely sclerosed, presenting the appearances characteristic of *false-joint formation.* (Plate 13, Fig. 5.)

Epiphysial Separations

An epiphysis in any part of the skeletal system may be separated at any time before bony fusion with the diaphysis has occurred.

In practice it is found, however, that only one epiphysis is separated with any degree of frequency ; this is the lower epiphysis of the radius, which quite commonly undergoes backward displacement. Elsewhere epiphysial separation is an injury of considerable rarity, the vast majority of lesions formerly so described being juxta-epiphysial fractures of the diaphysis. Separation of the lower epiphysis of the humerus, though still frequently diagnosed, is, in point of fact, one of the rarest of bony injuries.

A separated epiphysis nearly always carries with it a small fragment of one margin of the diaphysis, e.g. a fragment of the posterior margin of the radial diaphysis is nearly always detached and carried back with the epiphysis in this common separation.

If first seen after complete reduction, the nature of the lesion is generally made obvious by recognition of a small fissure passing through the diaphysial margin into the epiphysial cartilage ; should this be absent, increased depth of the space normally occupied by the epiphysial cartilage is strongly suggestive of a separation. Separated epiphyses, if completely reduced, rarely cause any recognizable deformity in adult life ; but slight irregularity of ossification around the diaphysial margins is often seen for several years after the injury.

Adolescent coxa vara consists of a separation of the epiphysis of the femoral head ; the lesion occurs between the ages of 13 and 17, is more common in the male, and presents many points of interest. The initial displacement which can be demonstrated in the skiagram is very slight. This tends to increase gradually, in the absence of treatment, up to a point when a sudden exacerbation of symptoms is associated with a very marked increase in the deformity. The inception of the separation does not appear to depend on any definite trauma, although subsequent trauma may determine a rapid increase in displacement.

In the earliest recognizable stage a skiagram of both hips will show a slight asymmetry of form. On the affected side the projection of the femoral head upwards from the upper margin of the neck is slightly diminished, while a small angulation may be seen in the normally regular curve known as Shenton's line (*see* p. 17). Later, a more definite coxa-vara deformity is seen, due to displacement upwards of the neck upon the head of the femur, and also to a rotation outwards of the diaphysis. The latter results in a characteristic radiographic abnormality : routine examination of the hip-joint is made with the inner border of the foot vertical—i.e. the external

rotation of the diaphysis present in these cases is corrected; this produces an abnormal internal rotation of the separated epiphysis, the outline of which is seen in the skiagram as an ellipse, approximating to a circle in extreme cases. It is important to realize that this apparent abnormal shape of the femoral head is due solely to the plane in which the part is seen, not to any deformity of the head itself. (Plate 14, Fig. 1.)

In old cases of adolescent coxa vara complete fusion is seen between the head and neck of the femur. Some slight curvature of the femoral neck is noted, resulting from adaptation of ossification to the abnormal relationship of the parts, but the site of the original deformity is still sufficiently obvious.

Infantile coxa vara is often bilateral, and the pathology is a matter of dispute. A very early epiphysial separation, however, would appear to explain the subsequent deformity. (*See* under Development of the Femur, p. 18.)

In the skiagram marked abnormality in the form of the upper end of the femur is seen. The femoral neck is horizontal, and appears to join the shaft at an abnormally low level, the great trochanter thus assuming an undue prominence. The plane of the epiphysial cartilage between the head and neck is considerably altered, being nearly or quite vertical. There is also some abnormality in lamellar arrangement in the great trochanter and neck, but no destructive or reactionary change is seen. (Plate 14, Fig. 2.) In adults the deformity is often extreme, the lower border of the femoral neck forming an acute angle with the shaft.

DISLOCATIONS

This injury may affect any articulation. Dislocations are seen frequently, however, only in the acromio-clavicular, shoulder- and elbow-joints. Partial dislocation of the ankle-joint as a complication of fractures in this region is also fairly common.

The lesion is recognized in the skiagram by the abnormal relationship of the articular extremities to one another. (Plate 12, Fig. 4.) Careful examination must be made for any complicating fracture.

In the normal adult **acromio-clavicular joint** an imaginary line continuing the lower border of the clavicle becomes continuous with the lower border of the acromion process. Alteration in this relationship is indicative of a subluxation or dislocation. (Plate 14, Fig. 3.)

In **dislocations of the shoulder-joint** the head of the humerus is seen to overlap to a greater or less extent the anterior margin of the glenoid cavity. Stereoscopic skiagrams may help to determine whether the head has passed forwards or backwards; or

a comparison of antero-posterior and postero-anterior views will often elucidate this point, the shadow of the head being larger in the skiagram in which it is farther from the plate. Fracture of the greater tuberosity of the humerus is a very common complication. (Plate 12, Fig. 5.)

In **dislocation of the elbow-joint** the bones of the forearm are most commonly displaced backwards and outwards. Fractures of the coronoid process of the ulna and the head of the radius may complicate the dislocation, and small fragments of bone are often detached by the lateral ligaments.

Dislocation forwards of the head of the radius occurs occasionally in young children, often in conjunction with a fracture of the shaft of the ulna. The frequency of this injury appears to have been exaggerated in the past.

Dislocation of the ankle-joint is a complication of fracture of the malleoli, and especially of the posterior margin of the tibia. (Plate 14, Fig. 4.)

Spondylolisthesis.—This condition of subluxation or dislocation forwards of the 5th lumbar vertebra upon the sacrum is rare, but probably improvements in radiographic technique will tend to show the lesion in many more instances than is at present possible. The lateral view only is of value in diagnosis, antero-posterior views, either single or stereoscopic, providing no definite evidence; and really good lateral views of this region in the adult are very difficult to obtain. In spondylolisthesis two abnormalities are seen in a satisfactory skiagram :

(1) A displacement forwards of the inferior articular processes of the 5th lumbar vertebra upon the articular processes of the first piece of the sacrum, or a fracture of one of these processes.

(2) A displacement forwards of the body of the 5th lumbar vertebra upon the sacrum. This is best determined by tracing downwards from the lumbar region into the sacrum the anterior border of the spinal canal, formed by the posterior surfaces of the vertebral bodies. This border shows a somewhat abrupt curvature at the lumbo-sacral junction which varies widely in different individuals, but the lumbar and sacral portions unite to form a definitely continuous border if prolonged across the intervertebral disc. When displacement forwards of the 5th lumbar vertebra has occurred this continuity is lost, and an abrupt interruption is found at the junction of the lumbar and sacral portions of the border. The posterior wall of the spinal canal should also be traced downwards for confirmation. The appearance of the anterior aspect of the vertebral bodies in the lumbo-sacral region forms a much less reliable guide than that detailed above, as a definitely angular junction of varying degree is here the rule.

DISLOCATIONS

Subluxations between adjoining articular processes on one side are not very uncommon in the lumbar region. The antero-posterior skiagram shows an angular lateral deformity between two vertebræ, and definite displacement between the adjoining articular processes, with or without fracture, on the side of the concavity. There is no abnormality of the vertebral bodies, and no loss of detail in the articular processes to indicate an inflammatory lesion.

Unilateral dislocations of the sacro-iliac synchondrosis are common in fractures of the pubic and ischial rami. The clinical condition known as **sacro-iliac strain** or **loose sacro-iliac joint** is not accompanied by any abnormality in the skiagram.

Recurrent dislocations.—It is unusual to obtain any evidence from the skiagram to explain this condition, the articular extremities being, as a rule, quite normal. In longstanding cases secondary osteo-arthritic changes may be seen.

Pathological dislocation may result from any destructive lesion of articular surfaces, or, in some joints, from longstanding inflammatory affections of the periarticular tissues. The changes resulting from the primary lesion are usually quite obvious, and the nature of the dislocation is thus rendered clear.

ABNORMALITIES OF BONES AND JOINTS (*continued*)

4. INFLAMMATORY LESIONS

IT is impossible to form any reliable estimate as to the period which must elapse between an infection of bone and the appearance of recognizable changes in the skiagram. The period during which the skiagram fails to provide any evidence of disease is found, in fact, to vary widely in different instances. In general, it may be stated that the more acute lesions, accompanied by extensive and rapid destruction of bone, are productive of earlier radiographic abnormalities than infections of lesser virulence. The point to emphasize, however, is that in the earliest stages of all bone-infections the skiagram is normal. In the case of joint lesions, when the infection is of the synovial type, this absence of radiographic abnormality is even more pronounced, and may persist for weeks or even months.

When the changes characteristic of an inflammatory bone lesion are seen in the skiagram it may be impossible to form any definite opinion as to the organism concerned ; very typical appearances are, however, often produced by infections with certain organisms, and in the presence of these a complete diagnosis can be made with considerable confidence.

Pyogenic infections.—The earliest radiographic evidence of an *acute* pyogenic infection consists of an area of rarefaction, usually central, but occasionally cortical in position, and more or less rounded in shape. The margins are ill defined, and loss of detail in bone structure is always present, most marked in the centre of the rarefied area.

The rarefaction and loss of detail become rapidly more extensive, but soon show marked irregularity of distribution, multiple areas of extreme rarefaction (and later complete loss of bone-shadow) being separated by bone in which the destructive change is much less in evidence. Reactionary changes appear, as a rule, fairly early in the course of the disease, and consist of periostitis and new-bone formation, the new bone tending at first to be regular, but later irregular, in distribution and structure (Plate 15) ; replacement of bone destroyed
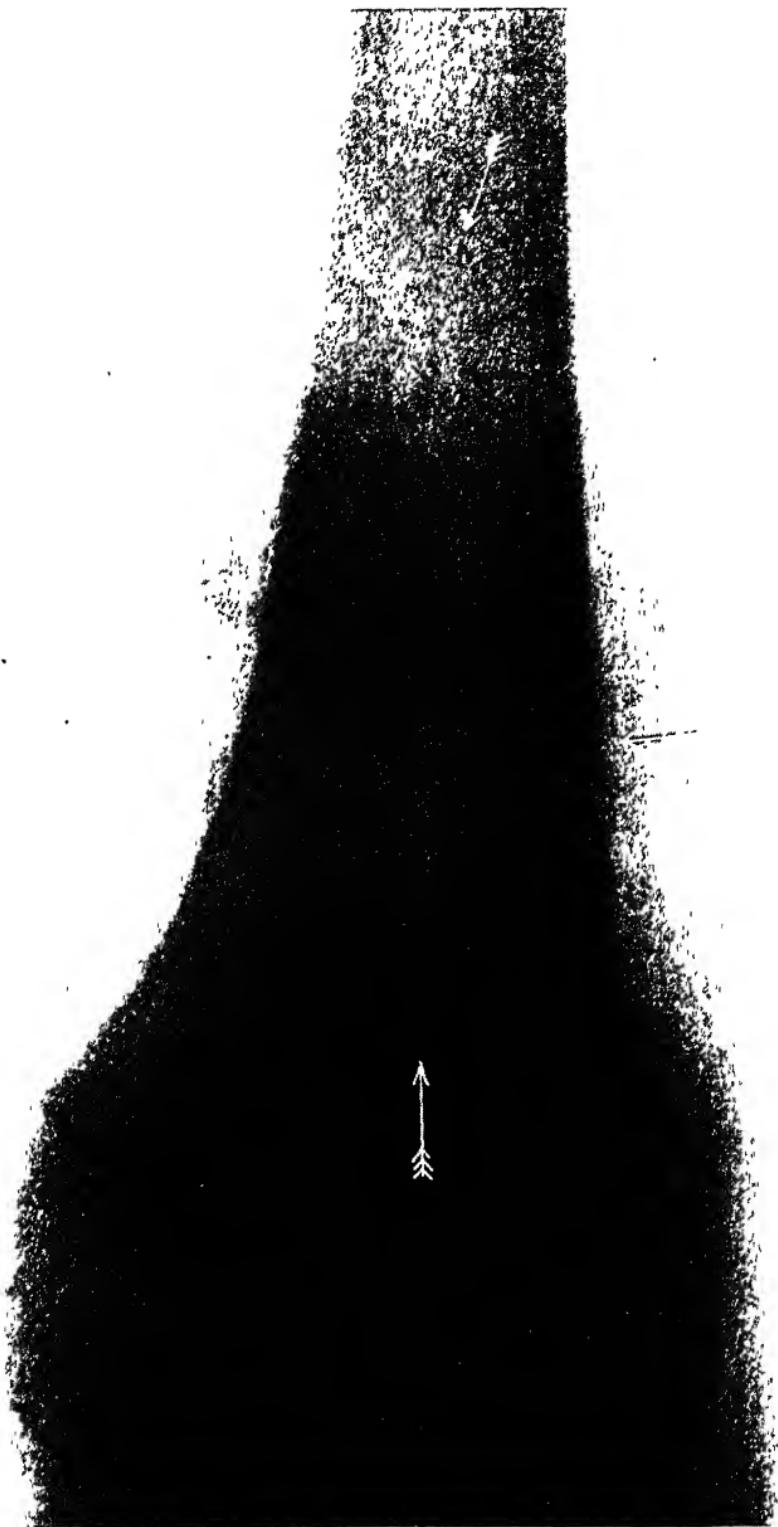
Acute pyogenic osteomyelitis at an early stage.

PLATE 15.
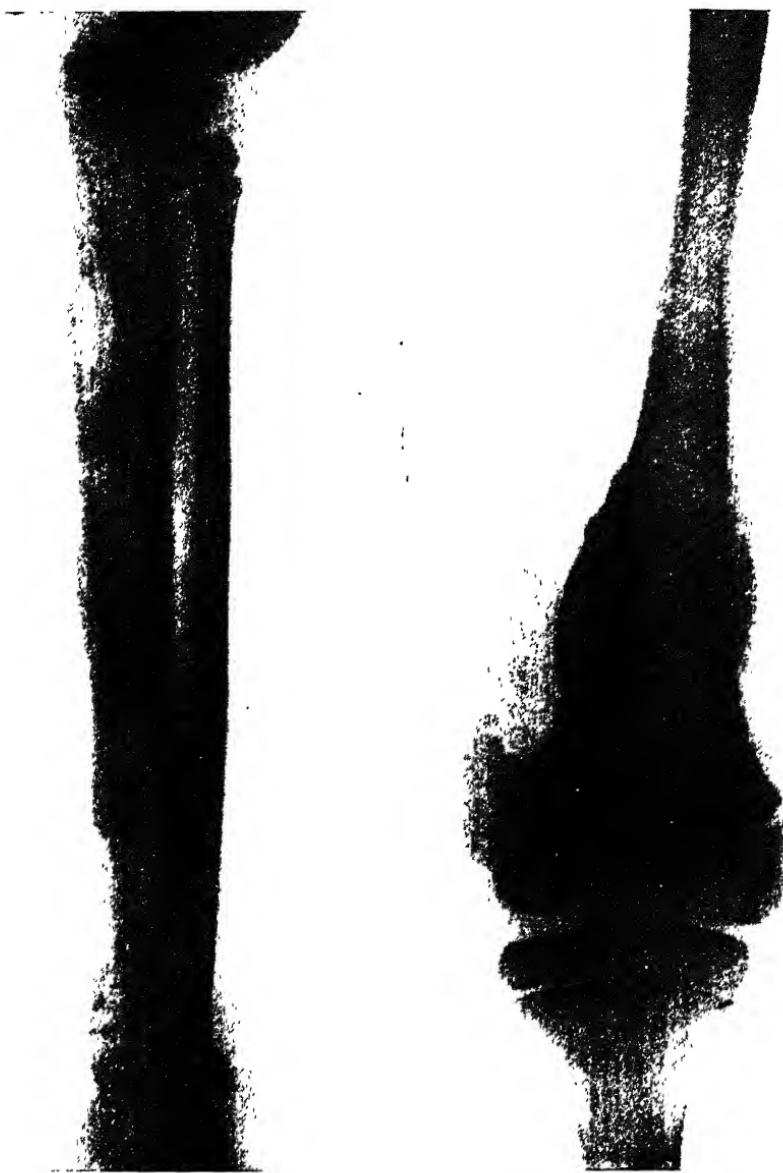
Fig. 1.—Acute pyogenic osteomyelitis of tibia.   Fig. 2.—Acute pyogenic osteomyelitis of femur with involvement of knee-joint.

PLATE 16.

Fig. 1.—Acute pyogenic osteomyelitis of tibia, with sequestrum-formation (sequestra marked with arrows).
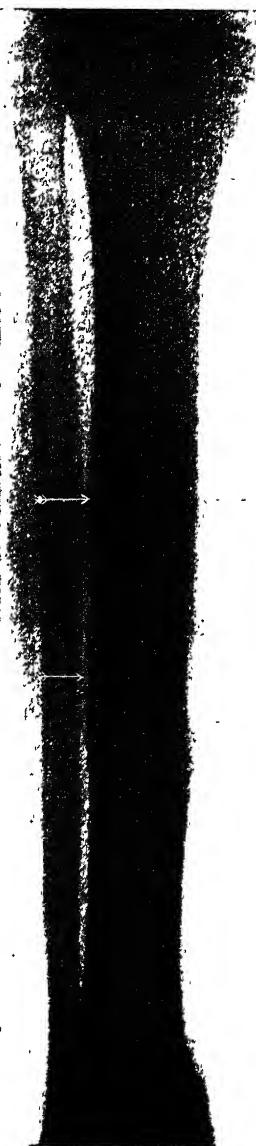
Fig. 2.—Subacute pyogenic cortical infection of tibia.

PLATE 17.
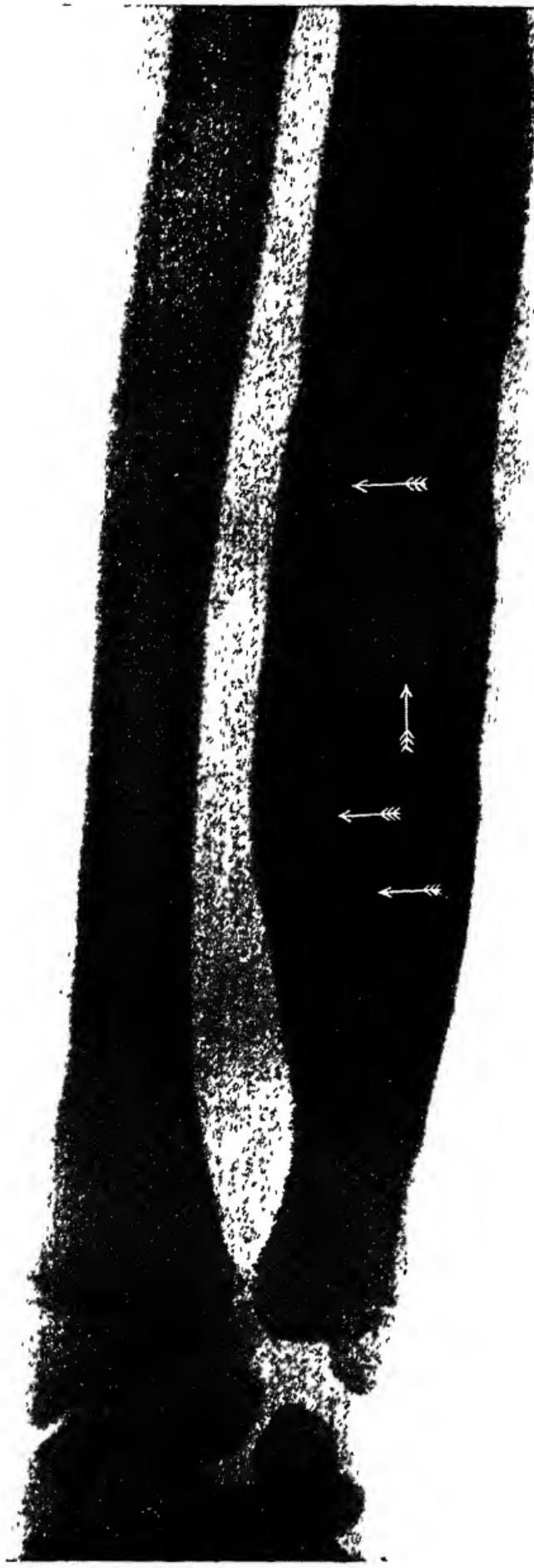
Subacute central pyogenic osteomyelitis of ulna with diffuse
hyperostosis.

PLATE 18.

by the inflammatory process occurs in a later stage of the lesion, co-incidently with sclerosis, and both processes show extreme irregularity. A typical case of *acute osteomyelitis* of some weeks' duration presents the following appearances : Widespread and irregular areas of rare-faction and loss of detail, the central portions of which may show complete loss of bone-shadow (abscess cavity), with or without an unattached structureless opacity (sequestrum-formation) ; separated by areas of bone showing comparatively normal structure, lesser degrees of destructive changes, or sclerosis with irregular new-bone formation. Subperiosteal new bone is excessive, producing gross abnormalities of size and form, and is irregular both in structure and in density, showing areas of destruction and sclerosis similar to those in the underlying shaft. (Plate 16, Figs. 1, 2, and Plate 17, Fig. 1.)

Subsidence of the inflammatory process is accompanied by a gradual return of detail in bony structure, and in a completely healed lesion lamellar detail can be demonstrated throughout the affected bone, except when obscured by extremely dense sclerosis.

The end-result of an acute pyogenic osteomyelitis presents abnor-malities in size and form owing to subperiosteal new-bone formation, and extreme abnormalities of structure, irregular areas of sclerosis and new-bone formation being intermingled with areas of compara-tively normal density and lamellar arrangement ; multiple small cavities are nearly always present, often with densely sclerosed walls, and sometimes containing sequestra.

The characteristic feature of this infection is the very widespread and completely irregular distribution of both destructive and reac-tionary changes ; the reactionary processes tending to become quite disproportionate to the preceding destruction.

Pyogenic infections which are *subacute* or *chronic* from the outset frequently arise in and are confined to the subperiosteal or cortical tissues. Destructive changes are slight, and consist of localized rare-faction and loss of detail, with some loss of bone-shadow ; the latter forming a defect in the surface of the cortex (caries), or sometimes representing an abscess cavity in the substance of the cortex. Re-actionary changes preponderate, and result in fairly regular sub-periosteal new bone which blends with the cortex, and a regular sclerosis both of the new bone and of the underlying shaft. In an old healed lesion of this type the skiagram shows a dense periosteal node, with sclerosis of the underlying cortex, the changes being fairly localized and usually quite regular in distribution. (Plate 17, Fig. 2.)

Should the subacute forms of infection be central in origin, a small deeply-placed cavity is seen. There may be surrounding changes similar in quality to those found in acute forms of the disease, but much more limited in extent and in degree. Sometimes, however, a

E

diffuse overgrowth of bone, perfectly normal in structure and density, is seen around the central cavity, with no other change whatever. (Plate 18.)

Pyogenic infection of joints.—Pyogenic infection of a joint may result from direct extension of an acute osteomyelitis to the articular surface; this surface then shares in the irregular destructive process seen in the remainder of the affected bone. The articular cartilage is quickly destroyed, with resultant diminution or complete loss of the joint-space; the opposing articular surface is frequently infected, but the destructive changes here are usually very localized. Reactionary changes in articular surfaces are inconspicuous or absent during the active stages of the disease, but a slight irregular sclerosis may be seen. (Plate 16.)

As healing takes place, new bone frequently forms between the closely applied eroded surfaces, resulting in a complete bony ankylosis. This condition can only be diagnosed from the skiagram if definite continuity of bone structure is seen between some part of the opposing articular extremities.

Pyogenic arthritis is often the result of an infection from the blood-stream, and the primary lesion is then synovial. The radiographic appearances are characterized by a rapid erosion and removal of the articular cartilages, resulting in diminution and finally loss of the joint-space; this is accompanied by destruction of the bony articular cortex. The destruction is most extensive where pressure is greatest. There is generally no reaction whatever in the active stage of the disease, the articular surfaces, after erosion of the cortex, being formed of cancellous bone, the spaces of which open freely on the joint-cavity. The actual destructive changes also are generally entirely confined to the region of the articulation, but widespread changes characteristic of acute bone-atrophy are sometimes seen.

As the lesion heals, sclerosis may occur, producing an irregular cortex covering the eroded cancellous tissue; or new-bone formation between the opposing cancellous surfaces may result in bony ankylosis. This type of arthritis is seen in pyæmia, and may also occur as a result of some remote unsuspected focal infection (e.g. in connexion with the teeth or tonsils). In the latter case the joint-changes often take place very slowly, and radiographic appearances may remain normal over a considerable period. (Plate 19, Figs. 1, 2.)

Tuberculous infections. — Tuberculous lesions from the radiographic standpoint form two groups, which may be named for convenience the _destructive_ and the _proliferative_ types. In neither instance is this designation strictly accurate, as will be seen later, but the adoption of these terms is useful as an indication of the predominating abnormality in the skiagram,
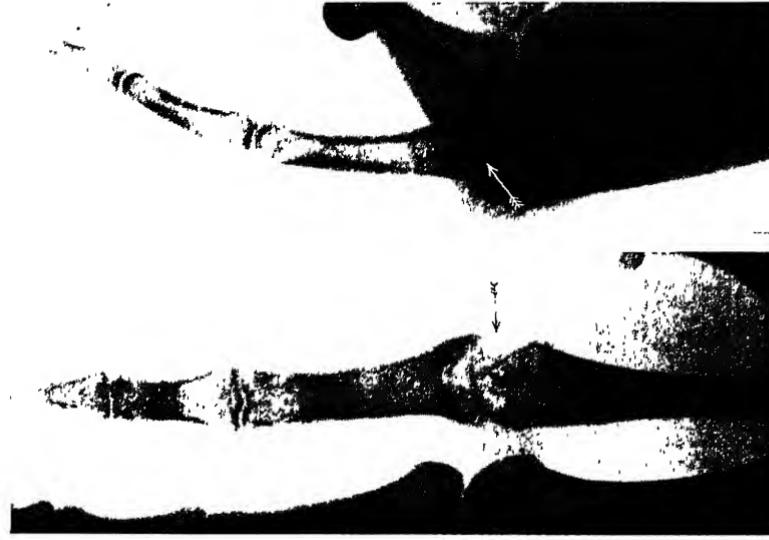
Fig. 1.—Infective arthritis (non-tuberculous).

Fig. 2.—Infective arthritis (non-tuberculous).

PLATE 19.
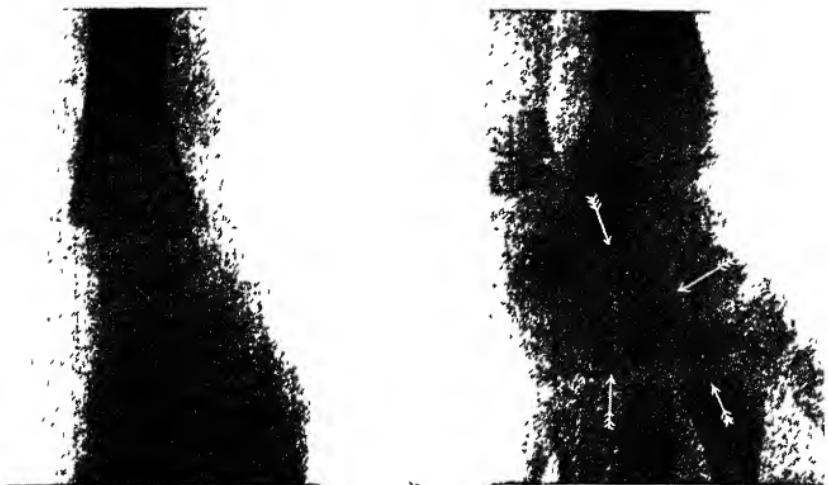
Fig. 1.—Tuberculous arthritis of carpus.
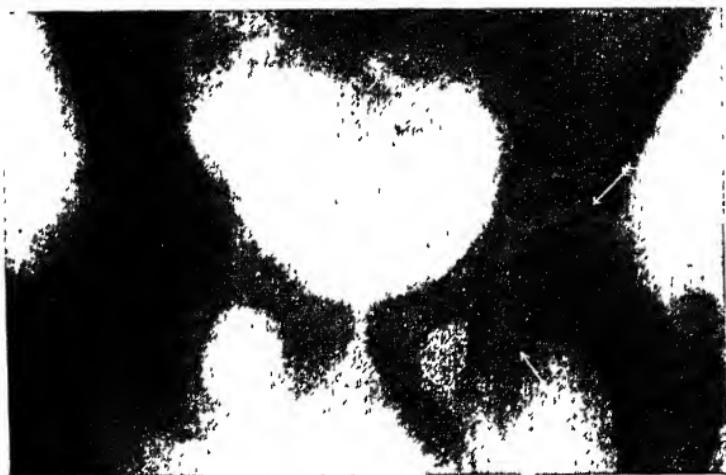
Fig. 2.—Active tuberculous arthritis of hip. Bone destruction confined to acetabulum.

Fig. 3.—Active tuberculous arthritis of hip.

PLATE 20.

The destructive type is much the more common, and is invariably seen in tuberculous lesions of the spine, and of the joints in cases where any bony changes in addition to general atrophy are demonstrated. A primary synovial infection is unaccompanied by radiographic changes until some bony involvement has occurred, except in superficial joints such as the knee or ankle : here it may be possible to demonstrate a definite opacity corresponding in position to a thickened and distended capsule ; if well marked, this abnormality is very characteristic of synovial tuberculosis, as it is seen in no other disease, but careful comparison must be made with the corresponding sound joint before advancing a diagnosis when, as is much more frequently the case, the increased capsular opacity is less definite. Involvement of the articular surfaces generally takes place in a primary synovial lesion. The skiagram then shows progressive destruction of the articular cortex, and later of the underlying cancellous bone, the loss of bone eventually being excessive. Erosion is preceded by a narrow zone of loss of detail. In spite of the extensive destruction, the radiographic changes are confined to the immediate vicinity of the articular extremities— e.g. the head of the femur may be almost entirely destroyed, but the neck will show no structural changes. This extensive destruction with localization of bone-changes to the surfaces which are undergoing erosion is characteristic of a tuberculous infection.

Two other points are of the utmost importance in differentiating tuberculous from pyogenic joint infections :

(1) In both infections, while active, new-bone formation is practically absent, but in tuberculous lesions the eroded bony surfaces often show a loss of detail and slightly increased density due to a fairly regular deposition of opaque salts. This is absent in pyogenic infections.

(2) In tuberculous lesions the articular cartilage, although often destroyed, is not dissolved ; the result being that the joint-space for a long time undergoes comparatively little diminution in width. In pyogenic infections, on the other hand, the articular cartilage, once destroyed, is rapidly dissolved by proteolytic ferments, and the joint-space is in consequence early diminished or lost. (Plate 20, Fig. 1.)

Tuberculous arthritis often results from a primary focus of infection in bone. This is first seen as an area of rarefaction and loss of detail in the articular extremity, usually just to one or other side of the epiphysial cartilage. The destructive change proceeds to complete loss of bone-shadow, and the area involved increases in size. Reactionary changes are generally completely absent.

Involvement of the joint-cavity takes place by direct extension of the destructive process on to an articular surface or to the synovial membrane. In either case the articular surfaces eventually undergo

the changes described above. It is not uncommon to see two or even more distinct foci in the region of the epiphysial cartilages in this type of infection. (Plate 20, Figs. 2, 3.)

Sequestra are not very common in pure tuberculous infections, but are sometimes formed from the articular surfaces, or from underlying cancellous bone when the articular cortex has been destroyed. They present the same radiographic characteristics as the sequestra found in pyogenic infections. (Plate 21, Fig. 2.)

Tuberculous caries of the spine.—The articular processes are sometimes the site of infection, and the radiographic changes in these are similar to those of other tuberculous joint lesions ; in addition, an angular spinal deformity results from collapse of the affected processes. Far more commonly the vertebral bodies are involved, the adjacent surfaces of two or more bodies being eroded. The appearances are identical with those of erosion of other articular surfaces, i.e. loss of detail precedes a superficial but progressive destruction, and a faint marginal zone of condensation is often seen. The intervertebral discs between the affected bodies are, moreover, rapidly destroyed, and destruction of the discs and of the bony surfaces is accompanied by simultaneous collapse, producing kyphosis—i.e. the eroded surfaces are never separated by any considerable interval. These two points, early erosion of the discs and comparative approximation of the eroded bony surfaces, are of great importance in differentiating tuberculous caries from crush fracture (in which the disc is unaffected) and from secondary deposit of neoplasm (in which the disc is not destroyed until a later stage, and collapse is often delayed). (Plate 22, Fig. 1. Cf. Plate 13, Fig. 1, and Plate 33, Fig. 2.)

The proliferative type of tuberculous lesion is seen in the metacarpals and metatarsals, the phalanges, and sometimes in the shafts of the larger long bones, especially the ulna. The earliest radiographic change generally consists in a widespread periostitis, resulting in the formation of successive orderly layers of subperiosteal bone parallel to the surface of the shaft. These layers of new bone are separated from one another by a narrow interval, and usually surround the shaft for the greater part of its length. Soon after the appearance of this new-bone formation it is generally possible to make out a central focus of rarefaction, loss of detail and, later, destruction ; this represents the primary focus of infection. The radiographic changes in the shaft itself are generally entirely destructive, reactionary changes being confined to the subperiosteal proliferation.

In the small bones of the hand and foot the central destruction often becomes extensive, and involves the subperiosteal new bone, so that the shaft appears as an expanded shell of bone, somewhat resembling the condition of enchondroma. The loss of detail in the zone
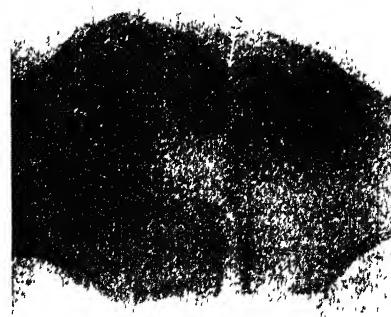
Fig. 1.—Tuberculous dactylitis of first phalanges of index and little fingers.

Fig. 2.—Tuberculous arthritis of knee - joint, with

Fig. 1.—Caries of dorsal spine.
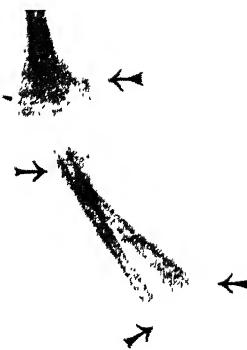
Fig. 2.—Syphilitic epiphysitis

Fig. 3.—Syphilitic dactylitis.

Fig. 4.—Syphilitic peri⟨

PLATE 22.

around the central destruction, however extensive this may be, indicates the inflammatory nature of the lesion. (Plate 21, Fig. 1.)

Healing of a tuberculous bone lesion is indicated by complete restoration of detail in bone structure throughout the skiagram. Deformity of shape and irregular lamellar arrangement are permanent, and do not affect the question of activity.

Central areas of destruction tend to be diminished in size and eventually obliterated by the formation of cancellous bone of fairly normal density and structure. Sclerosis is usually slight or completely absent.

Progressive improvement in structural detail, with absence of further destruction, as seen in serial skiagrams, indicates quiescence of the disease. Bony ankylosis of old tuberculous joints is not very common ; the diagnosis rests upon recognition of definite continuity of bone structure between some parts of the opposing articular extremities.

Bone-atrophy in tuberculous lesions.—As previously noted, the first or irregular stage of acute bone-atrophy rarely if ever occurs in tuberculous infections. It is often stated that a regular, so-called " vitreous " rarefaction, resulting from diminution in number and size of lamellæ, without any loss of structural detail, is typical of the disease. In point of fact, however, generalized atrophy of any sort is conspicuous by its absence in the vast majority of tuberculous lesions, except as a result of prolonged immobilization and disuse, and its appearance in these circumstances is valueless as regards differential diagnosis of the infective organism.

Syphilitic lesions.—Syphilitic lesions of bone are quite rare in comparison with the prevalence of the disease. Epiphysitis is, of course, confined to congenital infection, but the other lesions described below are common to both congenital and acquired syphilis.

In syphilitic epiphysitis the lesions are always multiple. Erosion of the epiphysial aspects of the diaphyses is seen, often accompanied by some displacement of the epiphysis if this is visible. Periostitis and subperiosteal new-bone formation surround the diaphysial extremities and extend a considerable distance up the shafts, becoming gradually less marked as the extremities are receded from. No other disease produces in infants multiple destructive and reactionary changes originating at the diaphysial extremities, and the radiographic appearances are therefore pathognomonic. (Plate 22, Fig. 2.)

Syphilitic periostitis.—The skiagram in this condition shows an extensive subperiosteal new-bone formation in orderly layers, roughly parallel to one another and to the cortex. The shaft of a long bone may be surrounded, or the periostitis may affect one aspect only, in which case it tends to involve a convex rather than a concave

surface. In this way normal convexities are exaggerated, while concavities are retained unaltered. Destructive changes, either central or cortical, are entirely absent, this serving to differentiate the lesion from other forms of extensive periostitis (notably the proliferative type of tuberculous infection); nor are any reactionary changes seen in the underlying bone structure—i.e. the lesion in its active phase is a pure periostitis. (Plate 22, Fig. 4.) In old healed lesions some of the new bone is absorbed, and the deeper layers blend with the underlying cortex, producing a cortical layer of abnormal thickness, but normal in density and lamellar structure. The increase in width of the cortex may be accentuated by conversion of cancellous into cortical structure, with subsequent diminution in width of the cancellous tissue and even sometimes of the medullary canal.

Localized gummata may be central or cortical in origin. In the latter case they are frequently multiple. It may be stated at the outset that radiographic differentiation of localized gumma from malignant neoplasm of bone often presents the greatest difficulty, and may be impossible in some situations, when the bone-changes are imperfectly seen (e.g. in the vault of the skull). *Central gumma* of bone in its earliest stages produces rapid central destruction, which may be complete over a single area, or diffuse and irregular, the destructive process infiltrating the bone, with retention of intervening comparatively normal bone structure. There is very little rarefaction or loss of detail preceding the destruction. If seen at this time, differentiation from an endosteal malignant neoplasm is impossible. Fortunately this stage is transient, reactionary changes speedily making their appearance. The reaction consists in periostitis and, later, subperiosteal new-bone formation. The new bone is rarely great in amount, but is usually typical of inflammatory reaction—i.e. it is regular, fairly dense, and laid down in layers parallel to the cortex; even if, as in Plate 23, Fig. 1, the lamellæ tend to form vertically to the cortex, their regularity and density are sufficient indication of the inflammatory nature of the lesion.

The frequently irregular infiltration of the destructive process, and the slight degree of preceding rarefaction or loss of detail, differentiate the lesion from a central tuberculous focus ; while the latter feature, together with absence of reaction in the substance of the shaft, usually enables a pyogenic infection to be excluded.

Cortical gummata. — In this condition the skiagram shows a progressive, irregular destruction, starting on the surface of the cortex and eventually extending into the cancellous tissue. A considerable area of the cortex is often involved. The destruction is not preceded by any marked degree of rarefaction or loss of detail. Periostitis and subperiosteal new-bone formation are absent or are
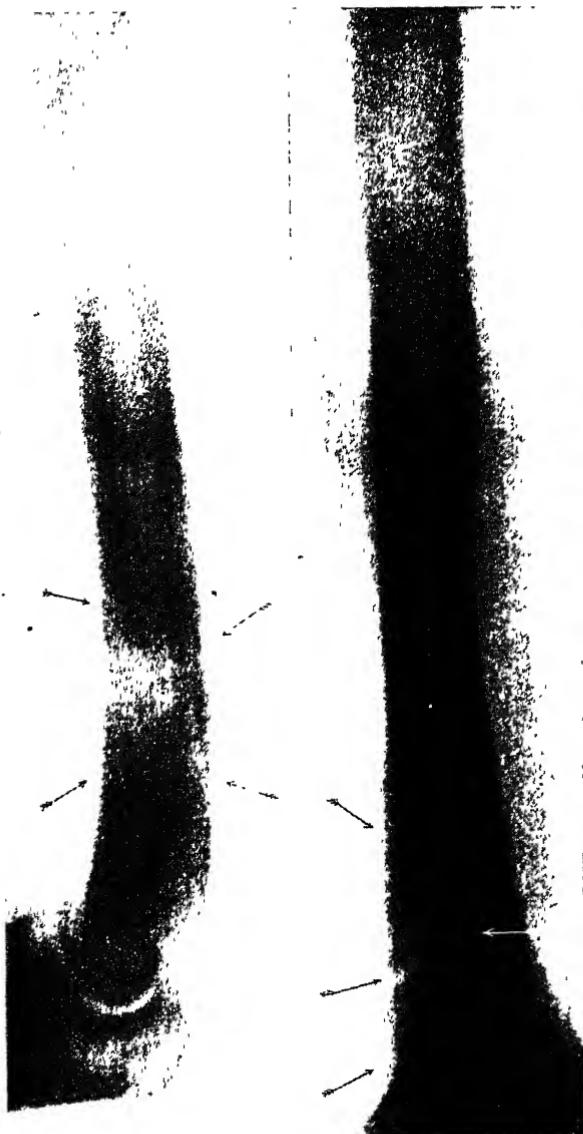
Fig. 1.—Central gumma of humerus, with incomplete spontaneous fracture.

Fig. 2.—Cortical gumma

PLATE 23.

Diffuse gummatous infiltration of radius and ulna

PLATE 24.

confined to the margins of the eroded area. A little new-bone formation is often seen, but this is of cancellous structure and irregular lamellar arrangement, and represents a reaction in the eroded subcortical cancellous tissue. In longstanding cases a little superficial sclerosis occurs, and small irregular areas may be seen deeply placed in the substance of the bone. (Plate 23, Fig. 2.) Healing is generally accompanied by a dense but fairly localized and regular sclerosis.

Diffuse gummatous infiltration.—In this condition a widespread, extremely irregular destructive process is seen, involving both cancellous and cortical tissue. It is not possible to recognize any particular areas as forming the primary focus of disease. Here, as in the preceding types of bone syphilis, destruction is not preceded by any marked degree of rarefaction or loss of detail. Lamellar arrangement is often exceedingly irregular, owing to formation of irregular cancellous bone both centrally and on the surface, the latter producing abnormalities in size and outline. Sclerosis during the active stages of the disease is slight or absent. Periostitis is inconspicuous and confined to the margins of the disease ; new-bone formation on the surface of the shaft resembles that seen in cortical gummata —i.e. it is of irregular cancellous structure, and often moderately extensive. (Plates 24, 25.)

Healing of this lesion is accompanied by irregular, fairly dense sclerosis. It should be noted that localized healed inflammatory lesions of bone often present no radiographic characteristics which establish a diagnosis of the organism originally involved. This statement does not apply to an old acute pyogenic osteomyelitis, the appear-ances of which are usually quite typical, even when the disease is completely healed.

Charcot's arthropathy.—This lesion is rarely seen until a fairly advanced stage has been reached. The skiagram then shows destruction of the articular cartilages, with loss of joint-space, and extensive destruction of the articular extremities where these are the seat of pressure. There is no reactionary change whatever in the eroded surfaces, nor any loss of detail preceding erosion ; the eroded surfaces present the appearances of normal cancellous bone. Multiple intra-articular fractures are common, and subluxation or complete dislocation often occurs. At a late stage the joint is seen to be completely disorganized, but there are still no changes suggestive of an infective arthritis (e.g. loss of bone detail or reaction). Irregular plaques of bone are sometimes formed in the ligaments, but these have no direct connexion with the eroded surfaces. (Plate 26, Fig. 1.)

If seen in an early stage, the disease cannot be distinguished with

certainty from an osteo-arthritis showing unusual erosion and comparatively slight osteophytic formation.

Gonococcal infections of the joints are frequently unaccompanied by any abnormality in the skiagram. In many cases the first stage of acute bone-atrophy is seen, but this is not in any way pathognomonic of a gonococcal infection. It is, however, of value in excluding tuberculosis, in which condition the first stage of bone-atrophy is rarely if ever observed. The most characteristic appearance, but one which is by no means common, consists of a marked irregular rarefaction and loss of detail confined to the cancellous tissue immediately adjacent to the articular cortex; the cortex and joint-space showing no variation from the normal. (Plate 26, Fig. 3.)

Suppurative gonococcal arthritis produces changes which are indistinguishable from those of pyogenic infections—i.e. there is diminution or loss of joint-space and erosion of the articular cortex and of the underlying cancellous bone.

Pneumococcal infections of bone produce changes which bear a general resemblance to a pyogenic osteomyelitis, but which are usually much more localized and accompanied by much less reactionary change. Pneumococcal periostitis in young children produces a fairly characteristic appearance, the thickened periosteum being seen widely separated over a large area without any changes in the underlying bone. Pneumococcal infections of joints are commonly unaccompanied by any radiographic abnormality.

Post-exanthematous arthritis.—The arthritis which sometimes follows scarlet fever, measles, smallpox, etc., produces appearances in the skiagram similar to those of pyogenic infections; the destructive changes, however, are generally more extensive than is common in the synovial type of pyogenic infection, approximating in this respect to a tuberculous lesion; the early erosion of the articular cartilage and absence of any irregular deposition of opaque salts in the eroded surfaces generally serve, however, to exclude tuberculosis. (Plate 26, Fig. 2.)

Smallpox occurring in young subjects is sometimes followed by multiple bone deformities. These have only been observed in adult life, so that the original changes are unknown. The deformities consist of defective growth in length of the long bones, especially those of the hands. The girth of the bones is normal. Bony ankylosis of the adjacent joints may also be observed, and Sheldon suggests that the deficient growth results from an infective arthritis.*

"Typhoid spine" is rarely seen in Great Britain. Completely divergent accounts have been published by observers who have considerable experience of the lesions; for example, it is stated that

* *Amer. Journ. of Roent.*, 1923.
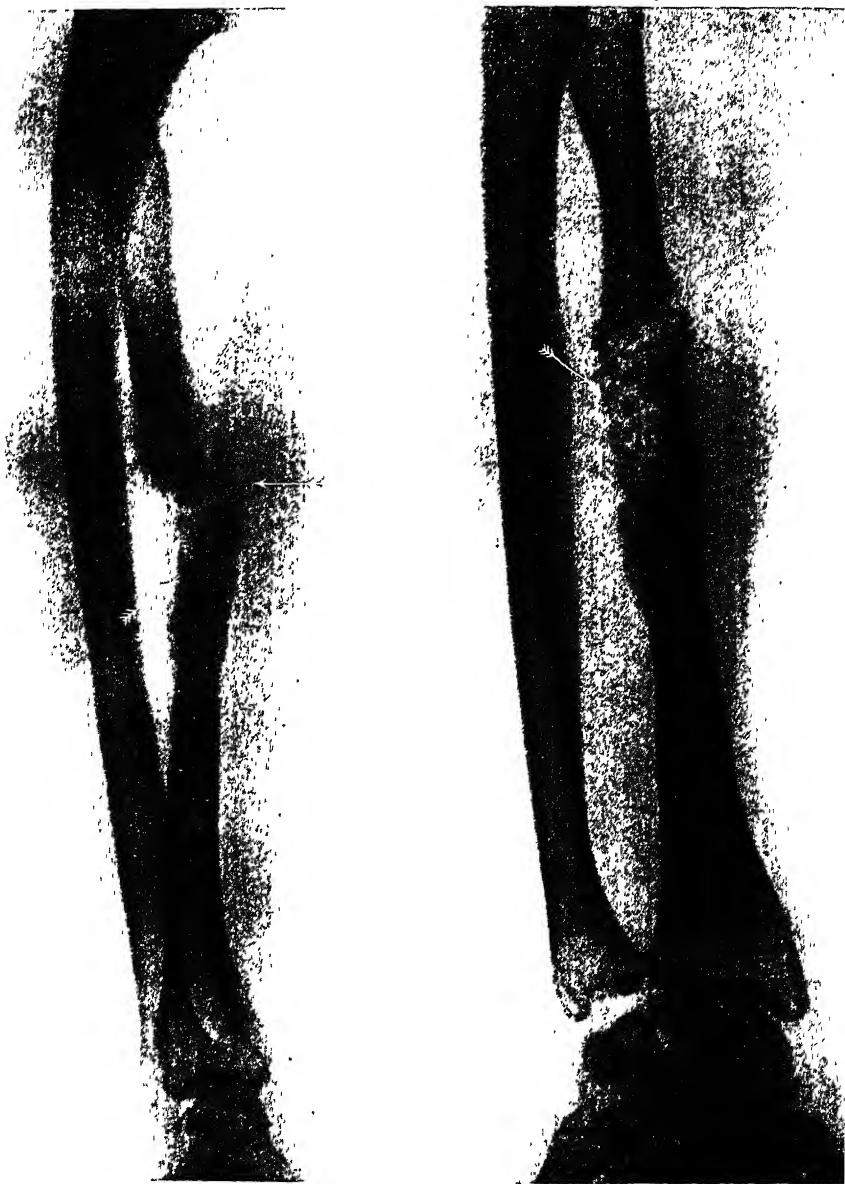
Diffuse gummatous infiltration of radius with spontaneous fracture.

PLATE 25.

Fig. 1.—Charcot's disease of knee-joint.

Fig. 2.—Post-exanthematous arthritis of hip.

Fig. 3.—Gonococcal infection of knee-joint

PLATE 26.

the appearances resemble tuberculosis, but that destruction of the intervertebral disc is absent ; again, that the disc is eroded and bony ankylosis supervenes ; and yet again, that bony outgrowths similar to those of a localized spondylitis deformans form the most prominent radiographic changes. It is quite obvious, therefore, that typhoidal spondylitis may be associated with very varying appearances in the skiagram, and that correlation with the clinical features of the case is necessary for exact diagnosis.

5. NEOPLASTIC DISEASES

Neoplasms of bone may be classified as benign and malignant, and the distinction between the two classes can be drawn radiographically with great accuracy, although, as will be seen later, a more detailed diagnosis is often impossible.

All neoplasms possess one radiographic characteristic which is often of the greatest value in differentiation from an inflammatory lesion : *articular surfaces are never the site of origin of the disease, and are only involved by extension after widespread destruction has occurred in the adjacent bone.*

BENIGN NEOPLASMS

Osteomata produce abnormalities in form. The cancellous osteoma, much the more common variety, is seen as a projection from the surface, having a thin cortical layer enclosing central cancellous tissue. The cancellous tissue may show some irregularity of lamellar arrangement but no other structual abnormality, and both cortical and cancellous lamellæ are directly continuous with the corresponding structure of the parent shaft. The superficial layers of the cortex covering the extremity of the outgrowth may show some loss of detail and irregular calcification, these appearances indicating extension of ossification into the cartilaginous cap covering the osteoma ; otherwise the cortex shows no structural abnormality. There is complete absence of any destructive change either in the tumour or the underlying shaft. (Plate 27, Fig. 1.)

Cancellous osteomata frequently arise near an epiphysial cartilage, but this localization is by no means invariable. The multiple osteomata seen in diaphysial aclasis have already been described (*see* Chapter IV, p. 32).

Compact or ivory osteomata are rare, and are almost confined to the skull and pelvis. They produce opacities of so great a density that it is usually impossible to distinguish any bony structure. The opacity is directly continuous, by means of a sessile attachment with the underlying cortex. (Plate 27, Fig. 2.) Occasionally a zone of destruction around the base of the osteoma indicates necrosis which

eventually separates the tumour from the parent bone ; with this
exception destructive changes are absent.

Chondromata are most frequently seen in the long bones of
the hand, and are then frequently multiple. The majority arise
under the periosteum, and produce very typical abnormalities in
form of the bones involved. The shaft appears to have undergone
an irregular, often extreme constriction, frequently with overhanging
margins above and below. The constriction may involve one aspect
only, but more usually surrounds the shaft. In spite of this very
marked deformity the structure is retained intact—i.e. a normal
cortex can be traced around the constricted portion, and the can-
cellous tissue, though necessarily diminished in bulk, shows unaltered
lamellar architecture. (Plate 27, Fig. 3.)

Central chondromata may occur in conjunction with the
subperiosteal type, but are often isolated growths in the hands and
feet. Since they are radiographically indistinguishable from other
benign central neoplasms they will be considered later (p. 59).

Large ossifying chondromata are sometimes seen, usually
growing from the bones of the pelvis. They produce an extensive
opacity in the skiagram, showing a somewhat ill-defined cancellous
structure, the lamellæ radiating from the surface of the underlying
cortex. There is some superficial resemblance to the radiating ossifica-
tion of periosteal sarcoma, but the new-bone formation in the benign
growth is much more extensive, and the trabeculæ are thicker, denser
and more closely arranged than in sarcoma. If the parent bone
can be demonstrated it will be seen to present some deformity in
outline but no invasion by destructive processes ; the size and density
of the tumour, however, often effectually obscure the bone from which
it springs, so that this point cannot be determined. (Plate 27, Fig. 4.)

Benign central tumours of bone, both solid and cystic,
present many histological varieties. Radiographically, however, no
essential distinction exists between the appearances of fluid cyst,
central chondroma, myeloma, and fibro-cystic disease. The following
description of benign central tumour applies to all these lesions, and
is followed by a brief note of any minor differences which may point
to a more exact diagnosis. The overwhelming importance of radio-
logical diagnosis in these central neoplasms consists in differentiating
the benign from the malignant, and this is possible in the vast majority
of cases.

The skiagram of a benign central tumour shows an area of complete
loss of bone-shadow ; the margins of this area are perfectly defined,
consisting of a thin layer of compact bone of normal structure ; the
cancellous tissue external to this thin compact zone shows no abnormal-
ity whatever. So-called " expansion " really consists in the formation

Fig. 5. -Myeloma of ulna.

Fig. 3.—Multiple chondromas.

Fig. 1.—Pedunculated exostosis.
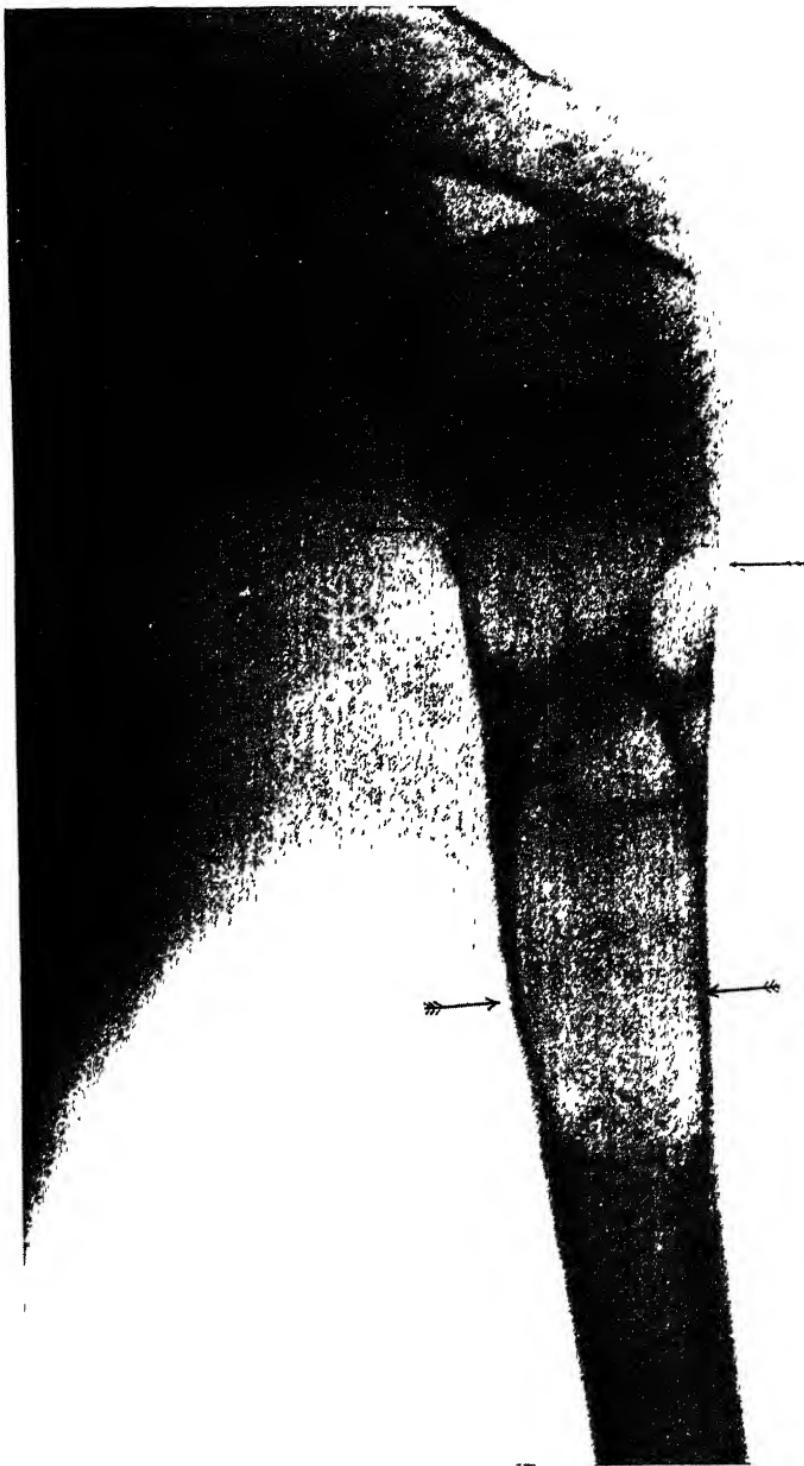
Fibro-cystic disease of humerus

PLATE 28.

Fig. 1.— Enchondroma of fourth metacarpal.

Fig. 2.—Large cyst in scaphoid. Fracture of lower end of radius.

PLATE 29.

Fig. 1.—Fibro-sarcoma of tibia (very slowly growing). Spontaneous fracture with some bony union.

Fig. 2.—Endosteal sarcoma of angle of scapula (rapidly growing).

of new subperiosteal bone of normal structure, and this takes place only when the original cortex has become involved in the destructive process.   The new-bone formation eventually fails to keep pace with the destructive process, and, when this occurs, erosion of the thin shell of bone at one or more points can be seen.   Pathological fractures are very common, and frequently lead to the detection of disease hitherto unsuspected.

Fractures are often followed by partial restoration of the bone formerly destroyed, callus being seen to invade the central area, and bony union taking place rapidly.   Even when complete restoration of bone appears to have taken place, however, recurrence of the destructive process is the rule.

Complete curettage of the central cavity is followed by gradual and permanent repair.   In old cases which have been cured in this way some slight abnormality of lamellar arrangement, and possibly a little irregularity of cortical contour, constitute the only radiographic evidence of the original lesion.   Sometimes an indication may be obtained as to the nature of the central tumour :

Myeloma (giant-celled sarcoma) occurs most commonly in the upper and lower extremities of the radius and the upper end of the humerus.   It is more frequent in adults than in children, and tends to cause considerable irregular " expansion," so that the area of destruction is roughly spherical.   It is commonly stated that the central area is crossed by trabeculæ, but this appearance is largely due to irregularities in the shell of bone enclosing a tumour which presents superficial lobulation.   (Plate 27, Fig. 5.)

Fluid cysts and fibrous cysts are common in the upper third of the humerus in children, and the upper end of the tibia and lower end of the femur in adults.   They rarely produce much " expansion," but tend to spread in the long axis of the bone.   The simulation of trabeculæ crossing the cavity is therefore unusual.   (Plate 28.)

Central chondroma is rarely seen except in the long bones of the hand and foot.   Moreover, this neoplasm forms the vast majority of benign central tumours in these situations.   Chondromata tend to spread in the long axis of the shaft, but also produce a moderate degree of " expansion."   (Plate 29, Fig. 1.)

Cysts are very common in the carpus, especially the scaphoid, in which bone they may attain a considerable size.   (Plate 29, Fig. 2.) In some instances cysts have been observed to develop in the scaphoid after an injury, suggesting that the process is in these cases a degeneration.   In other instances, however, myelomatous tissue has been found at operation.

The majority of carpal cysts are very small, remain stationary in size over long periods, and are only recognized when some unconnected

incident necessitates a radiographic examination. It would appear rare for them to assume any clinical significance.

MALIGNANT NEOPLASMS

In the characteristic radiographic appearance of malignant neoplasms destruction of bone predominates. The destruction is irregular and diffuse, and no margin can be determined as limiting the process. There is very little, if any, rarefaction or loss of detail in bone structure preceding the complete loss of bone-shadow ; towards the periphery of the lesion it is common to see isolated spicules of normal bone projecting into the area of destruction. In the most typical malignant neoplasm—i.e. a rapidly growing endosteal sarcoma—reactionary changes are often entirely absent. In other neoplasms new-bone formation may be present, and may for a time be excessive, as described below. The new bone seen in these cases, however, differs from that of inflammatory lesions in being generally purposeless in distribution— i.e. there is no arrangement suggestive of repair of the tissue eroded. When subperiosteal new bone is formed, this is rarely noted until the cortex has been completely destroyed at some point, and the new bone is then insignificant in quantity and quickly shares in the general destructive process.

It will be apparent that no great difficulty arises in distinguishing benign from malignant neoplasms ; the absence of any clearly defined margin limiting the destructive process is sufficient to establish the malignancy of the growth. The distinction between a malignant neoplasm and an inflammatory lesion, on the other hand, often presents great and sometimes insuperable difficulty ; this was commented upon in the description of central gumma of bone. The points of greatest importance in differentiating malignant neoplasm from inflammatory diseases are :

(1) The very irregular destruction of bone without any preceding rarefaction or loss of detail.

(2) The absence of any effectual attempt at repair by new-bone formation. It must be recognized that localized repair occasionally takes place in some of the very slowly growing neoplasms ; but consideration of the skiagram as a whole will show, even in these rare instances, that destruction outstrips any purposeful reaction. (Plate 30, Fig. 1.)

The variations in radiographic appearances produced by the different malignant neoplasms must now be considered.

Endosteal sarcoma, if rapidly growing, produces a complete loss of bone-shadow, possessing no definite margins. Reaction is quite absent until the cortex has been eroded at some point. A small

Fig. 1.—Endosteal sarcoma of tibia (rapidly growing).

Fig. 2.—Endosteal sarcoma of femur.

PLATE 31.

Periosteal sarcoma of femur.

Dr. ... 29

projection of subperiosteal new bone may then be seen at the margins of the cortical destruction, but this in its turn is soon destroyed. (Plate 30, Fig. 2, and Plate 31, Figs. 1, 2.) A slowly growing central sarcoma, such as fibro-sarcoma (Plate 30, Fig. 1), may show a definite limiting margin to destruction at one or more points, but this margin is always incomplete ; over a great extent of the periphery no defined limit can be made out. A certain amount of transient repair may also be seen in parts of the affected area, but repair is generally ineffectual and localized. A little subperiosteal new-bone formation is commonly seen, but when this is eroded it is not replaced—there is no real appearance of successive attempts to restrict the tumour within bony walls, as in the " expansion " of benign growth.

Periosteal sarcoma is a rare form of neoplasm. If taken at an early stage the skiagram shows a bundle of delicate, feathery bone trabeculæ radiating from the surface of the cortex. Destructive changes may be absent, or slight cortical destruction below the new-bone formation may be seen. At a somewhat later stage, erosion of the cortex is quite obvious, and this is followed by extension of the destructive process into the cancellous tissue. Eventually the new-bone formation shares in the general erosion, and involvement of the parent bone is so extensive that the site of origin of the growth can no longer be recognized—i.e. in advanced stages periosteal and endosteal sarcomata are indistinguishable.

Apart from the new-bone formation seen in the initial stages of the disease, reactionary changes are generally entirely absent in periosteal sarcoma.

The destructive changes are characteristic of malignant neoplasm —i.e. they are progressive, are not limited by any recognizable margin, and take place without preceding rarefaction or loss of bony detail. (Plate 32.)

In slowly-growing neoplasms of this nature the ossification in the tumour substance predominates for a time over the destructive process, and the skiagram then shows considerable extension of fine radiating trabeculæ from the parent bone, and sometimes isolated areas of similar fine trabeculæ in the more peripheral portions of the growth. These so-called " ossifying sarcomata " present no essential difference in their radiographic appearances from the more rapidly growing examples of periosteal sarcoma.

Secondary sarcomatous deposits in bone frequently produce the purely destructive process characteristic of central malignant neoplasm, and are then indistinguishable radiographically from primary endosteal sarcoma unless multiple lesions can be demonstrated. Occasionally a sarcomatous deposit stimulates a considerable reaction in the surrounding bone, which may completely obscure for a time

the underlying destructive process. This is most commonly seen in the spine, in which situation the recognition in a single vertebral body of greatly increased opacity, without erosion of the intervertebral disc, is almost pathognomonic of such a deposit.

Extensive new-bone formation in the substance of a secondary deposit in the long bones is sometimes seen, and presents the purposeless irregular distribution and delicate feathery trabecular formation characteristic of ossification in malignant growths.   (Plate 33, Fig. 1.)

Secondary carcinomatous deposits nearly always produce purely destructive lesions, the only notable exception being the metastasis of prostatic carcinoma, which frequently shows a certain amount of ossification.

Carcinomatous deposits often show a central area of destruction, and several peripheral areas, separated by normal bone ; the method of production apparently being by emboli from the central deposit. This appearance is fairly characteristic of secondary carcinoma, which cannot otherwise be distinguished from secondary sarcoma.

Carcinomatous deposits are exceedingly common in the vertebral bodies, and there produce the destruction without preceding bone change which is characteristic of malignant neoplasm. Collapse is delayed owing to the solid nature of the tissue which has replaced the bone structure, and erosion of the intervertebral discs only occurs at an advanced stage of the disease. The delayed collapse and the integrity of the discs render easy the differentiation from spinal caries. (Plate 33, Fig. 2. Cf. with Plate 22, Fig. 1, and Plate 13, Fig. 1.)

6. PARASITIC DISEASE OF BONE

Hydatid cysts, when occurring in bone, are nearly always multiple ; they are, however, immediately contiguous, and produce in the skiagram a central destruction indistinguishable from that of central benign tumours. " Expansion " is usually absent, the destructive process extending in the long axis of the shaft, and the appearances therefore approximate to those described as characteristic of fibrous or fluid cyst rather than of myeloma.

Hydatid cysts in the spinal column produce destruction and, later, collapse of a vertebral body indistinguishable radiographically from secondary malignant deposits.

Fig. 1.—Ossifying sarcoma of humerus.
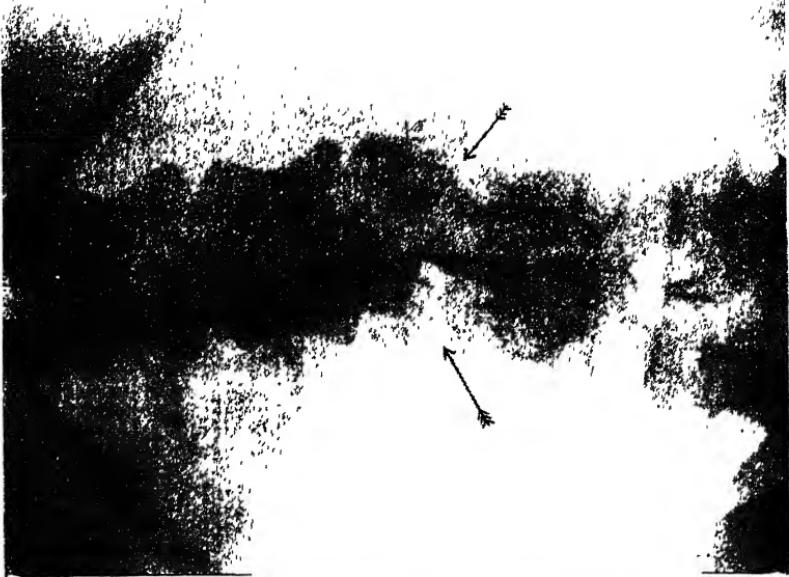
Fig. 2.—Secondary carcinoma of third lumbar vertebra.
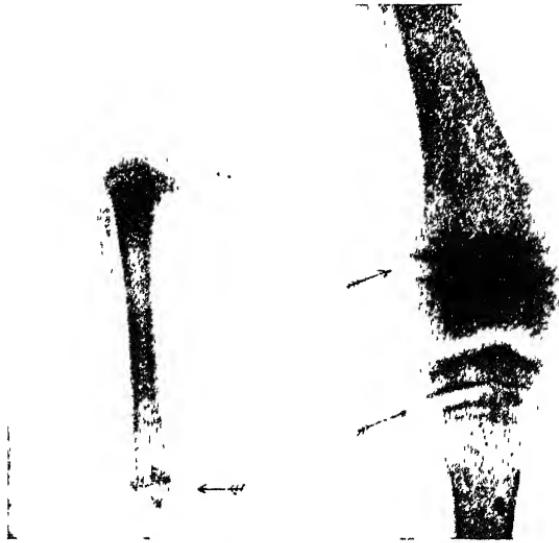
Fig. 1.—Rickets (active).

Fig. 2.—Late rickets.

Fig. 3.—Renal dwarfism.

Fig. 4.—Scurvy: subperiosteal
hæmorrhage.

PLATE 34.

CHAPTER VI

ABNORMALITIES OF BONES AND JOINTS (*concluded*)

7. ABNORMALITIES OF UNKNOWN OR DOUBTFUL PATHOLOGY

Infantile rickets. — This disease is often accompanied by characteristic abnormalities best seen in the epiphyses and shafts of the long bones, and subsequent deformities which may affect any part of the skeletal system. (It is by no means uncommon, however, to find a complete absence of bony abnormality in cases of well-marked clinical rickets.)

The extremities of the long bones present abnormalities of size, form and structure. The ends of the diaphyses are increased in girth, so as to overlap to an undue extent the epiphysial ossific nucleus. The epiphysial aspect of the diaphysis is somewhat hollowed out or " cupped," and a wide zone of very irregular ossification is seen instead of the normal, clearly-defined, regular, bony surface. The epiphysial cartilage is increased in depth as a result of this zone of irregular ossification. Ossification of the epiphyses is usually unaffected, but may be somewhat delayed. (Plate 34, Fig. 1.)

The shafts of the long bones show general rarefaction, due to deficiency of opaque salts, and this may be so extreme as to produce considerable loss of detail. The cortical layer is thinner than normal.

Curvatures often occur and are followed by new subperiosteal bone laid down in the concavity of the curve. Fractures are not very common in the absence of definite trauma

The bones of the vault of the skull share in the general rarefaction, and may undergo deformity from pressure. Closure of the sutures is delayed and the frontal eminences frequently become unduly prominent. Dorsal kyphosis is not infrequent, but no bony changes can generally be demonstrated in the vertebræ.

Rachitic coxa vara is distinguished from other forms by the recognition of the characteristic changes in the upper epiphysis of the femur. The deformity results from curvature of the femoral neck, or may be subtrochanteric.

Rickets is the commonest cause of flat pelvis, the conjugate diameter being diminished while the transverse is relatively increased.

Cure of the disease is signalized by an increased opacity of the shafts, but is best followed by observations in the epiphysial regions. Here the zone of ragged irregular ossification which forms the epiphysial aspect of the diaphysis gradually gives place to the normal clear-cut diaphysial extremity, separated from the epiphysial nucleus by a translucent area representing an epiphysial cartilage of normal depth. Complete restoration of regularity in the diaphysis is the best radiographic evidence of healing of the lesion. The increased girth of the diaphysial extremity is not diminished but is gradually compensated as general growth of the bone proceeds.

Various observers have described a horizontal zone of ossification occurring in the epiphysial cartilage, and tending to divide it into an epiphysial and a diaphysial portion ; this has been named the "line sign" and regarded as evidence of healing rickets. The author has never observed the occurrence, and considers that the description results from a failure to recognize the two margins of the diaphysis, which may occupy different planes in the skiagram.

In later childhood and adult life, rachitic subjects commonly show no evidence of the disease in the regions of the epiphyses. Deformities of the skull and pelvis persist ; deformities of the spine and long bones tend to become less marked during the later years of childhood, but are usually sufficiently obvious if suitable treatment has been neglected during the active stages of the disease.

In the adult skeleton a series of linear condensations is frequently seen extending across the diaphysial extremities ; this has been ascribed to infantile rickets, but there is no real evidence to support the supposition, and the true causation of this abnormality in ossification remains in doubt.

Late rickets.—This rare disease is seen between the ages of 8 and 18. The radiographic appearances bear a general resemblance to those of infantile rickets—i.e. the epiphysial cartilage is very markedly increased in depth, ossification of the epiphysial aspect of the diaphysis is irregular, and slight increased girth of the diaphysial extremities may be seen, especially in the younger subjects. Deformities such as are seen in infantile rickets may also occur, and it is possible that some spinal curvatures of obscure pathology are referable to this disease. (Plate 34, Fig. 2.)

Renal dwarfism.—Epiphysial changes are seen in this condition which bear a striking resemblance to those of late rickets, and radiographically the lesions may be indistinguishable. In many cases of renal dwarfism, however, " cupping " or hollowing out of the diaphysial extremity occurs to a very marked degree, with comparatively little increase in girth. The ossification of the diaphysial extremity also tends to form longitudinal striæ extending down from

Osteitis deformans (Paget's disease) of tibia.

PLATE 35.

Fig. 1.—Early osteitis deformans (Paget's disease) of pelvis, with secondary osteo arthritis of hip-joint.

Fig. 2.—Osteitis deformans (Paget's disease) of skull.

PLATE 36.

the deeper central portion of the cup towards the epiphysial cartilage
—i.e. the arrangement is more regular than in rickets. The shafts
of the stunted long bones present no characteristic changes. (Plate 34,
Fig. 3.)

Scurvy.—The earliest radiological evidence of this disease is
said to be the appearance of linear increase of opacity in the diaphyses,
a few millimetres from their extremities. Scurvy can rarely be recog-
nized with certainty, however, unless subperiosteal hæmorrhage occurs.
These hæmorrhages produce fairly dense, structureless opacities,
bounded by the raised and thickened periosteum externally, and in
immediate contact with the shaft internally. They are seen in the
region of the diaphysial extremities, which they commonly surround,
although often more prominent on one aspect. (Plate 34, Fig. 4.)

It must be remembered that scurvy and rickets frequently occur
coincidently, and the characteristic rachitic changes must not be
apportioned to the scorbutic element of the disease.

Osteitis deformans (Paget's disease).—From the radio-
graphic standpoint this disease presents early and late stages ; the ·
appearances of the early stage may persist for many years.

The changes seen in the *early phase* are best studied in a skiagram
of one of the long bones. The bone shows abnormalities in size, being
increased in girth ; abnormalities in form, being curved and frequently
irregular ; and remarkable abnormalities in structure.

The structural changes affect the lamellar arrangement, and are also
both destructive and reactionary, the latter change predominating.

The first recognizable alteration in structure consists in new sub-
periosteal bone-formation, laid down in fairly orderly layers parallel
to the surface. This new bone and the underlying shaft soon undergo
a loss of detail due to irregular extraction and deposition of opaque
salts. Linear translucent areas are then seen separating bundles
of lamellæ—i.e. there is complete loss of bone-shadow over multiple
areas without loss of lamellar continuity. This irregular spacing
out of lamellæ affects the new subperiosteal bone and the original
cortex, and the two frequently become indistinguishable. The can-
cellous tissue is also involved in this structural change, though to a
less extent than the more compact tissue.

Some of the linear interlamellar spaces may attain a moderate
size, simulating the appearance of small irregular cysts.

Elsewhere the structure is further modified by localized deposits
of opaque salts both in the bone tissue and in the intervening spaces,
resulting in multiple opacities of varying size tending to acquire a
uniform density and so obscure all detail in the area involved.

The processes described above are slowly progressive ; curvatures
of the shaft occur owing to bending of the softened bone, and these

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are exaggerated by the tendency of new subperiosteal bone to be laid down more on the convexity than in the concavity of the curve. (Plate 35).

The extremities of the long bones share, often to a marked extent, in the internal structural changes, and also undergo some enlargement by new subperiosteal bone-formation on their non-articular surfaces. Advanced osteo-arthritic changes are frequently seen in the adjoining articulations.

The pelvis and spine show the characteristic structural changes without, as a rule, very great new-bone formation. The pelvis is usually the first portion of the skeleton to be involved, and is frequently found to be affected in elderly men who present no clinical manifestation of Paget's disease. (Plate 36, Fig. 1.)

The changes in the vault of the skull are strictly comparable to those described as occurring elsewhere, and are most in evidence where the bones are seen in profile. The great increase in thickness of the vault appears to be due partly to extensive new-bone formation on the outer aspect of the outer table, which retains better-defined structure than is seen in the long bones, and partly to an increase in cancellous tissue between the inner and outer tables. This cancellous tissue shows extreme loss of detail as a result of the irregular deposition and extraction of opaque salts, the former producing multiple areas of uniform opacity similar to but more numerous than the corresponding opacities in the long bones. (Plate 36, Fig. 2.)

In the *late stage* of Paget's disease excessive uniform deposition of opaque salts obliterates all trace of bony structure, producing a uniform mortar-like opacity. This may be so dense as entirely to obscure the medullary canal in the long bones. When this stage is established no further new-bone formation is seen ; the disease appears to have reached quiescence.

Diffuse osteitis fibrosa.—There are at least two conditions, radiographically quite distinct, which are described under this name.

The first frequently affects one bone only, most commonly the radius or ulna, or upper end of the tibia. The bone involved shows abnormalities in size and form, being irregularly increased in girth and often in length, and may present curvatures. The structural changes consist in deposition of subperiosteal new bone, spaced out by longitudinal striæ of non-opaque tissue. This spacing out also affects the cortex and cancellous tissue, reducing the former to the opacity and general lamellar arrangement of the latter, so that the shaft presents no distinct division into cortical and cancellous layers. The loss of bone-shadow corresponding to the translucent striæ is not accompanied by loss of continuity of bone structure. Small, fairly dense, localized opacities are often seen in the substance of the shaft.

Fig. 1.—Osteitis fibrosa of ulna.   Fig. 2.—Osteitis fibrosa of humerus cystic type.

PLATE 37.

Fig. 1.—Perthes' disease.

Fig. 2.—Perthes' disease, healed.

PLATE 38.

The separation of the bone lamellæ is often of sufficient magnitude to suggest actual cyst-formation.

It will be seen that the appearances bear a strong resemblance to those of Paget's disease. The chief features distinguishing osteitis fibrosa consist in the comparative retention of bony detail, and the much more extensive spacing out of the bone lamellæ, with the formation of multiple, definitely cystic areas. The appearances remain unaltered over long periods. (Plate 37, Fig. 1.)

The other lesion described as diffuse osteitis fibrosa tends to involve the whole, or a great part of the skeleton. The appearances are those of multiple central cysts of large size, extending in the long axes of the shafts without producing any reaction until the cortex is nearly eroded, when spontaneous fracture generally occurs—i.e. there is a complete absence of "expansion." Individually these central areas of destruction are indistinguishable from central benign tumours of cystic or fibro-cystic type ; it is only the multiplicity of the lesions which is characteristic of the disease. The fractures which frequently occur unite rapidly, but with a minimum of callus-formation. (Plate 37, Fig. 2.)

Perthes' disease (syn. Calvé's disease, Legg's disease, Pseudo-coxalgia, Osteo-chondritis juvenilis). — This obscure disease of the hip-joint occurs between the ages of 5 and 10 years. The changes are generally unilateral, but sometimes bilateral. The disease sometimes supervenes after reduction of a congenital dislocation, but with this exception no history germane to the lesion is obtained.

The earliest radiographic abnormality consists of slight flattening and uniform increased density of the head of the femur ; next, the dense flattened head becomes fragmented—that is, irregular absorption of bone converts the single ossific nucleus into numerous small nuclei of irregular shape. About the same time as the appearance of fragmentation, or rather earlier, the femoral neck becomes deformed by an increase in vertical depth. This is apparently due to the formation of new bone on the upper aspect of the neck, although the actual process cannot be distinguished radiographically. Small areas of rarefaction often appear in the femoral neck, usually close to the lower part of the epiphysial cartilage, and similar rarefied areas can sometimes be recognized in the acetabulum, which may, in addition, show some irregularity of form. (Plate 38, Fig. 1.)

The ossification of the femoral head gradually increases again with disappearance of fragmentation, and as this occurs the head is seen to become enlarged in its upper and anterior portions, projecting out of the acetabulum to an abnormal extent above and in front ; the plane of the epiphysial cartilages also becomes altered in its upper

third, so that the head appears to spread outwards along the upper aspect of the neck.

Complete return to normal density and structure of the femoral head is regarded as evidence of healed disease. The deformity of the head and neck persists throughout life. In adult life the head of the femur is seen to be greatly enlarged, and to bulge out of the acetabulum above. There is often considerable flattening of the head. (Plate 38, Fig. 2.) Secondary osteo-arthritic changes frequently occur owing to the concentration of pressure over a small area in the upper part of the articulation. Many cases of so-called " morbus coxæ senilis " (which frequently develops in middle life) are obviously examples of this osteo-arthritic process developing in a joint previously the site of Perthes' disease.

Three theories are advanced as to the nature of this lesion :

(1) According to Jansen the disease is due to *developmental abnormality of the acetabulum*, resulting in flattening of the normal concavity and consequent concentration of pressure over the upper part of the articular surfaces. He considers that this flattening is due to one of two variations from the normal—either an increased thickness of the acetabular floor, or an adduction of the whole ischium. Skiagrams certainly do not always support this theory, which, moreover, offers no obvious explanation of the changes that mark the different stages of the disease.

(2) The *traumatic* theory receives support only from the occasional appearance of the disease after reduction of congenital dislocation. In no other instance is radiographic evidence of trauma obtained.

(3) The occurrence of rarefied areas in the diaphysial extremity and in the acetabulum is consistent with the theory that this is an *infective process*, and some support for this view has been obtained by exploration of these areas.

It is necessary to emphasize the fact that some cases of tuberculous arthritis may closely simulate the radiographic appearances of early Perthes' disease ; the diagnosis in early cases, therefore, must be very guarded.

Köhler's disease of the tarsal scaphoid.—The onset of clinical symptoms in this condition occurs between the ages of 5 and 7. The skiagram shows the scaphoid to be multinucleated, reduced in its antero-posterior diameter sometimes to a disc not more than one-eighth of an inch in thickness, and abnormally opaque. This increased density is apparently due to the shadows of many small ossific nuclei being superimposed upon one another in the skiagram. There is no approximation of the astragalus to the cuneiform bones, indicating that the cartilaginous bulk of the scaphoid remains unaltered.

More or less similar appearances are nearly always seen in the two

Fig. 1.—Kohler's disease.

Fig. 2.—Kohler's disease of second metatarso-phalangeal joint.

PLATE 39.

feet, although clinical symptoms are generally unilateral. This condition has never been seen to occur in a scaphoid previously normal, nor does it ever become accentuated at examinations subsequent to the first observation ; on the contrary, ossification gradually increases, the multiple nuclei fuse, and a normal scaphoid is seen at the end of about two years. No permanent deformity ever occurs.

It has been stated in a former chapter that ossification of the scaphoid from multiple nuclei is quite common ; in some instances the multinucleation is extreme, and an appearance identical with that of Köhler's disease is seen ; about two years after ossification has commenced the appearance of the scaphoid is normal. In the vast majority of children no clinical symptoms arise, and the frequency of multinuclear ossification is only recognized from many examinations of clinically normal subjects. It would appear, therefore, that Köhler's disease consists of some unknown factor producing the characteristic symptoms in a scaphoid which is developing from multiple nuclei, but that this method of development is in itself sufficiently common to merit classification as a variation of the more usual process rather than as an abnormality. It must be remembered in this connexion that multinucleation is common also in the cuneiforms and epiphyses of the metatarsals. There is no radiological evidence to support the commonly adopted grouping of Köhler's disease of the scaphoid with Perthes' disease of the hip. (Plate 39, Fig. 1.)

Köhler's essential disease of the 2nd metatarsophalangeal joint.—This rare disease originates between the ages of 10 and 18 years ; the resulting deformity persists throughout life. It is more common in females than in males, and in the right foot than the left. Occasionally the 3rd metatarso-phalangeal joint is affected, either alone, or in conjunction with the 2nd.

The skiagram shows the following abnormalities :*—

(1) The articular surface of the proximal phalanx loses its circular form and becomes irregular.

(2) The joint-space is increased, and more so in its outer portion than in the inner part.

(3) The articular surface of the head of the metatarsal becomes flattened, and later irregular.

(4) In longstanding cases circular opacities are seen in the region of the capsule and surrounding soft tissues.

(5) The head of the metatarsal is shortened in its distal third.

(6) The distal half of the shaft of the metatarsal is increased in girth. This is due partly to added cancellous tissue, partly to cortical proliferation. Bone structure is, however, unaltered. No periostitis is seen. (Plate 39, Fig. 2.)

* Köhler, *Amer. Journ. of Roent.*

In later life osteo-arthritic changes may occur in the affected joint. The nature of the disease is quite unknown.

Osteo-chondritis of the spine.—A few cases have been noted of dorsal kyphosis and scoliosis in childhood in which the skiagram shows, in the region of maximum deformity, a single vertebral body compressed, fragmented and of increased opacity. The intervertebral discs are intact. It has been suggested that this condition is analogous to Perthes' disease of the hip, and there are certainly clinical and radiological points of similarity. The later stages of the disease have not been observed with sufficient frequency as yet to warrant any description.

Kyphosis of puberty.—The deformity affects the upper and middle dorsal vertebræ, is first noticed at puberty or slightly later, and results in an extreme degree of dorsal kyphosis, which is progressive up to the age of about 20, and then becomes stationary. The skiagram shows anterior wedging of a number of dorsal vertebral bodies, without any change in bony structure suggestive of inflammatory disease. The upper and lower surfaces of the diaphyses show some irregularity, however, and the epiphysial plates, which appear about the time of onset, also show some irregularity of ossification. The intervertebral discs exhibit some diminution in depth anteriorly, thus sharing in the general deformity, but the discs are not destroyed. Secondary osteo-arthritic changes generally develop in early adult life.

The pathology of the disease is quite obscure. Late rickets has been suggested as the causation, but radiographic examination of the epiphyses of the long bones does not show any abnormality in these parts. (Plate 40, Fig. 1.)

Acromegaly.—No characteristic changes are seen in the enlarged bones of acromegaly, the skiagram showing a simple overgrowth of normal cancellous structure. The changes which may be found in the pituitary fossa as a result of pituitary enlargement are described in the chapter on the diagnosis of lesions in the central nervous system. The common cervico-dorsal kyphosis is seen to be accompanied by anterior wedging of the affected vertebral bodies without destructive changes.

Osteomalacia.—In this disease the entire skeleton undergoes extreme concentric and eccentric atrophy. The changes are best typified by a skiagram of one of the long bones. It will be seen that general rarefaction is so advanced that detail in bone structure is to a great extent lost. In extreme cases it is almost impossible to differentiate the cortex from the cancellous tissue ; in addition, the girth of the whole shaft is diminished and the width of the cortex becomes greatly reduced. The articular extremities, on the other

hand, while sharing in the general rarefaction, are not diminished in size, although frequently deformed; and the slender shaft with articular extremity of normal size results in the typical " drumstick " appearance.

Irregular curvatures are seen in the long bones, and coxa-vara deformity of the femora, but fractures are not very common.

Typical deformities occur in the pelvis and thorax, as follows :*

The sacrum develops an increased convexity backwards, the lower portion being carried forwards with the coccyx. The acetabula are pushed inwards with the adjacent pubes and ischial rami, producing the triradiate pelvic inlet; while the symphysis pubis projects forwards.

Scoliosis with rotation occurs in the upper dorsal spine; the sternum develops a marked convexity forwards, with approximation of its upper and lower extremities, and the chest becomes barrel-shaped.

Hypertrophic pulmonary osteo-arthropathy. — The changes seen in this disease consist of new subperiosteal bone laid down in fairly regular layers around the affected bones. There is some general rarefaction of the underlying bone, but no cortical erosion or central destruction, nor is there any loss of detail in bone structure. The characteristic feature of the radiographic appearances consists in the multiplicity and distribution of the lesions; any single lesion, considered alone, could not be differentiated from a periosteal proliferation without destruction, such as occurs in syphilis.

The bones most frequently affected are the shafts of the metacarpals and metatarsals, and the 1st and sometimes the 2nd row of phalanges, in all of which the proliferation is most marked around the centres of the shafts, fading off towards the articular extremities; and the lower thirds of the radius, ulna, tibia and fibula. In advanced cases all the long bones may be involved. In all the long bones, except those of the hand and foot, the periosteal proliferation affects the upper and lower thirds of the shafts, the middle third being comparatively immune.

The clubbing of the fingers is not accompanied by any changes in the third phalanges.

Erosion of the articular cartilages, with diminution of joint-space, is sometimes seen in those articulations which present swelling of the soft tissues (most commonly the wrists, ankles and knees).

Osteo-arthritis.—The radiographic diagnosis of osteo-arthritis depends on the recognition of the characteristic osteophytic formations at the margins of the articular surfaces. These osteophytes show the structure of compact bone. They have smooth surfaces, are usually fairly regular in shape, and may attain a large size; their

{* Maxwell and Miles, *Proc. Roy. Soc. Med.*, 1925, xviii. 4S–66.

direction is usually that of the joint-capsule. These smooth, comparatively orderly formations are readily distinguishable from the small, irregular, spiky, much more fragile outgrowths which are sometimes seen in rheumatoid arthritis.

In the later stages of osteo-arthritis, erosion of the articular cartilages results in diminution and ultimate loss of the joint-space ; erosion of the bony articular surfaces may follow, but is not accompanied by loss of the cortical articular layer, since subcortical cancellous bone is transformed into compact structure as superficial erosion proceeds.

There is never loss of detail in bony structure at any period during the course of the disease.

Ossification or calcification is not uncommon in the capsule and synovial fringes, and the latter condition may lead to actual opaque loose bodies in the joint. (Plate 40, Fig. 2.)

Bony ankylosis never occurs in osteo-arthritis. Osteo-arthritic changes are exceedingly common in middle-aged and elderly subjects, especially in the knee-joints, and are frequently unaccompanied by any symptoms or clinical evidence of the disease. Secondary osteo-arthritis nearly always develops sooner or later in a joint which has been damaged in any way ; the most striking examples of this are provided by cases of old intra-articular fractures, in which secondary osteo-arthritic changes are almost invariable, but similar changes frequently occur in old infective lesions which have healed with retention of movement. True secondary osteo-arthritis sometimes supervenes in joints previously damaged by rheumatoid arthritis.

In all cases of osteo-arthritis, therefore, the skiagram must be examined with a view to determining whether the disease is primary, or secondary to some preceding lesion.

Spondylitis deformans.—The radiographic appearances in the early stages of this disease suggest an osteo-arthritis of the spine —i.e. typical osteophytes are seen at the margins of the vertebral bodies, directed towards the next vertebra ; these are produced by ossification in the intervertebral ligaments. In a slightly more advanced stage these outgrowths are seen to exceed in length ordinary osteophytic formation, and two bony processes are often to be seen directed towards each other from adjacent vertebræ. Fusion of these bony outgrowths is the characteristic feature of the disease, serving to place it in a category distinct from osteo-arthritis, in which bony continuity is never established across an articulation. In a late stage of spondylitis deformans, ossification takes place in the intervertebral discs, and the portion of the spinal column affected shows complete bony ankylosis. (Plate 41, Fig. 1.)

The disease most commonly starts in the lower lumbar region,

Fig. 1.—Kyphosis of adolescence.

Fig. 2.—Osteo-arthritis of knee, with
large calcified body behind femur.

PLATE 40.

whence it spreads upwards, or in the lower dorsal region, when it extends both upwards and downwards.

Ordinary osteo-arthritis showing no tendency to fusion of the osteophytic outgrowths is very common in the mid-dorsal region, especially in old cases of kyphosis and scoliosis.

The specialized clinical types of spondylitis, such as spondylose rhizomélique, present no characteristic radiographic appearances, and are indistinguishable from the ordinary spondylitis described above.

Polyarticular rheumatoid arthritis.—As it appears probable that more than one disease is placed under this heading, it is not surprising that no radiographic appearances can be recognized as constant in every case of clinical rheumatoid arthritis.

In many instances no definite abnormality is seen in the skiagram ; when abnormalities occur they possess certain features in common :

(1) Multiple articulations are affected.

(2) The changes are best seen, as a rule, in the bones of the carpus and hands.

(3) General rarefaction, due to absorption of opaque salts and also to spacing out of lamellæ, is common, and is most marked in the articular extremities of the long bones and in the carpus.

(4) There is no loss of detail in bony structure.

This retention of perfect structural detail, combined with the multiplicity and distribution of the lesions generally, serves to differentiate rheumatoid arthritis from the more definite infective articular diseases.

In addition to the general rarefaction without loss of detail noted above, the following changes may be seen, either singly or in combination :

(1) Diminution or complete loss of joint-space, indicating erosion of the articular cartilages.

(2) Small rounded translucent areas in the subcortical tissue at the articular margins ; the superficial aspect of these areas is usually represented as a breach in continuity of the articular cortex, producing the so-called " punched-out " appearance.

(3) Erosion of the cortical articular surfaces, with subsequent erosion of the underlying cancellous tissue, producing in advanced cases complete disorganization of the articulation.   This is sometimes followed by bony ankylosis between the opposed cancellous surfaces.

(4) Subluxations in those joints which have been seriously disorganized.

(5) Small irregular spiky outgrowths around the margins of the damaged articular surfaces.

(6) Typical secondary osteo-arthritic changes in longstanding cases, when movement is retained.   (Plate 41, Fig. 2.)

In **Still's disease** the skiagram rarely shows any of the bony changes described above, but ossification of the carpus is generally in advance of that proper for the age of the patient.

Gouty arthritis presents no characteristic radiographic appearances. If any abnormality is seen, the changes approximate to those of osteo-arthritis or of rheumatoid arthritis, generally the former.

It has been suggested that the small punched-out areas described above as occurring in polyarticular rheumatoid arthritis are in fact characteristic of gout ; this has been conclusively disproved.*

Hæmophilic joints.—The initial hæmorrhage into any joint is not associated with definite abnormality in the skiagram.

Joints which have been the site of repeated hæmorrhages show a slight but definite increased opacity of the capsule, producing a somewhat cloudy appearance in the soft tissues ; there is in addition some diminution of joint-space, indicative of erosion of the articular cartilages, and sometimes slight irregularity of the underlying articular cortex.† Joints which have been damaged in this (as in any other) way eventually develop osteo-arthritic changes.

Syringomyelia.—Two types of arthropathy occur in this disease, hypertrophic and atrophic.

In the *hypertrophic* form of lesion the articular surfaces and underlying cancellous bone are destroyed. There is marked general rarefaction but no loss of detail. New-bone formation occurs in the ligaments and in the attachments of tendons, and the joint-capsule is often extensively calcified. The diaphysial extremities adjacent to the affected articulation often show considerable increase in girth due to subperiosteal new-bone formation, or irregular exostosis may be seen ;‡ this diaphysial proliferation forms the only radiographic distinction between the hypertrophic arthropathy of syringomyelia and Charcot's disease, and in many cases a differential diagnosis between the two lesions is impossible.

In the *atrophic* form the destructive processes are unaccompanied by new-bone formation or capsular calcification. As in the hypertrophic type, general rarefaction may be well marked, but detail is not affected.

Ossification in muscles, intermuscular septa and tendons.—The attachments of these structures to bone often become the seat of ossification, especially in elderly subjects. The new-bone formation is generally cancellous in type, is directly continuous with the underlying bone, and shows some irregularity of lamellar arrangement, but otherwise a normal structure. The pelvis is a common site

* McCarty, *Amer. Journ. of Roent.*, N.S., vii. 451–59, 1920.
† Klason, *Acta Radiologica*, vol. i., 1921.
‡ Marsh and Watson, " Diseases of the Joints and Spine."

Fig. 1.—Spondylitis deformans.

Fig. 2.—Rheumatoid arthritis.

Fig. 3.—Osteophytic spur of os calcis.

PLATE 41.

for this condition, which in the absence of pressure symptoms appears to be of no clinical moment.

In younger subjects, ossification extending into muscular or tendinous attachments is often the result of repeated overstrain, a good example being provided by the "*rider's bone,*" which consists in ossification of the adductor tendons. In these instances the new formation is more compact in structure, and is not necessarily directly continuous with the underlying bone.

Ossification of the posterior attachment of the plantar fascia sometimes occurs and constitutes the *calcaneal spur.* The condition is often bilateral, though generally asymmetrical. These spurs are of compact structure, and are directly continuous with the os calcis at the fascial attachment. They may attain a large size, and are sometimes fractured. (Plate 41, Fig. 3.)

Calcification of the posterior extremity of the plantar fascia, producing a structureless opacity not directly continuous with the os calcis, is said to result from gonorrhœal inflammation ; if this is so it is certainly of rare occurrence.

Myositis ossificans.—Ossification commences in the muscles of the back and neck, the bony formations being of cancellous type. The disease may extend to the other muscles in course of time. It is distinguished from traumatic myositis ossificans (p. 37) by the distribution and multiplicity of the lesions.

CHAPTER VII

THE ACCESSORY NASAL SINUSES AND MASTOID ANTRA

DESCRIPTION of the X-ray examination of the accessory nasal sinuses belongs anatomically to the section devoted to the Respiratory Tract. Radiographically, however, a much closer resemblance exists to the skeletal system, and it is therefore advisable to consider the sinuses in this place, and with them the mastoid antra, which present many similar diagnostic features.

The *frontal* and *ethmoidal* sinuses and the *maxillary antra* are investigated in symmetrical postero-anterior views of the skull; the *sphenoidal* sinuses are very plainly seen in a lateral view, but as the two sinuses are here superimposed it is better to obtain a skiagram from above downwards and forwards, so that the sinuses are seen between the upper and lower incisor teeth (the mouth being widely open), or below the inferior border of the mandible. (Plate 42, Fig. 1.)

In the normal subject these sinuses all show a very marked translucency as compared with the surrounding parts, in virtue of the air which they contain, and the bony walls of the sinuses are clearly defined.

The **frontal sinuses** vary greatly in shape and size, and are often strikingly asymmetrical. Frequently one, and sometimes both, of the sinuses are rudimentary or entirely absent. Well-developed sinuses are bounded below by the junction of horizontal and vertical plates of the frontal bone, and may extend back into the former structure; the outer and upper borders are usually of irregular trefoil shape. The division between the sinuses generally consists of a very thin bony plate in the mid-line.

The trefoil or irregular loculation partially divides each sinus into lobules which are unequal not only in their transverse, but also in their antero-posterior dimensions. This results in variations in translucency over different portions of the same sinus; and a similar inequality of translucency is also common between the right and left sinuses, regarded as a whole, on account of their asymmetry.

No rigid standard of comparison therefore exists whereby minor degrees of diminished translucency can be assigned to pathological

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Fig. 1.—Normal sphenoidal sinuses.

Fig. 2.—Normal maxillary antra, frontal and ethmoidal sinuses.

PLATE 42.
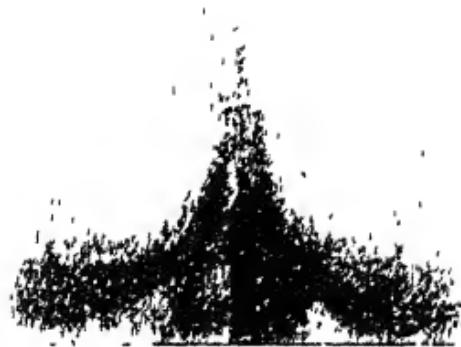
Fig. 1.—Empyema of frontal sinus.

Fig. 2.—Empyema of right maxillary antrum.

PLATE 43.

causes ; a frontal sinus which shows the translucency of contained air over its whole extent, and clearly defined bony margins, must be regarded as radiographically normal. (Plate 42, Fig. 2.)

Inflammatory disease of a frontal sinus results in loss of translucency owing to replacement of the normal air content by œdematous mucous membrane or by retained fluid. In the former case the translucency may be only diminished in extent, while in the latter there is uniform and complete loss of translucency. Even when air has thus been completely replaced, however, the slightly condensed margins of the sinus can be clearly seen, and the appearances are therefore distinguishable from those of rudimentary or absent frontal sinus. (Plate 43, Fig. 1.) Owing to the variations which occur in size and translucency of normal sinuses, the diagnosis of inflammatory disease in its early stages is sometimes exceedingly difficult. Generally speaking, a positive result is of mu h greater value than a negative one.

In cases of longstanding disease the bony margins of the sinus show irregular rarefaction and loss of detail due to caries.

Neoplasms of the frontal sinuses.—The only neoplasm which affects these sinuses with any frequency is the compact osteoma of the frontal bone, described in the preceding chapter. This produces an exceedingly dense opacity with smooth rounded margins encroaching upon the cavity of the sinus.

The **ethmoidal sinuses** present, in a postero-anterior skiagram, a translucent strip on either side, each strip being bounded externally by the inner wall of the orbit, and internally by the outer wall of the nasal fossa, which, with the turbinate bones, forms a rather wide, irregular opacity.

Above, the translucency of the ethmoidal cells is more or less continuous by means of the infundibulum with that of the frontal sinuses, while below no very clear demarcation exists from the maxillary antrum. The translucency of the ethmoidal sinuses is crossed by a number of thin, clearly-defined bony trabeculæ, representing the walls of the individual cells ; it is not possible to differentiate the anterior, middle, and posterior groups of cells with any degree of certainty.

Inflammatory disease of the ethmoidal sinuses results in loss of translucency and of definition in the walls dividing the cells from one another. Unilateral disease is readily recognized, as the sinuses are commonly symmetrical on the two sides, thus affording accurate data for comparison ; bilateral disease is sufficiently obvious if the sinuses are large, but may escape detection in very small sinuses.

Neoplasms usually involve the ethmoidal sinuses by extension, and are of malignant type. They may produce some displacement

of the lateral mass of the ethmoid as a whole in early stages, but soon result in erosion of bone.

The **maxillary antra** present areas of translucency roughly pyramidal in shape, the apices of the pyramids being directed outwards, and the bases abutting upon the lateral walls of the nasal fossæ. The antra are symmetrical in size and shape for practical purposes, and this symmetry also exists in the variations of translucency which occur over different portions of the sinuses as a result of superimposed bone-shadows. (Plate 42, Fig. 2.)

Inflammatory lesions of the antrum result in loss of translucency. This may be apparent as an irregular constriction of the translucent area, indicating œdema of the mucosa, or as a uniform opacity over the whole extent of the sinus, typical of empyema. Comparison of the two sides is of great value in unilateral lesions, but a clear mental conception of the normal appearances is necessary for correct interpretation in bilateral infections. (Plate 43, Fig. 2.)

It is by no means uncommon for the radiographic and clinical findings as regards the antrum to be at variance when an interval of time separates the two investigations. This does not indicate an error of interpretation, but is due to retention or drainage taking place between the two examinations.

Neoplasms of the antrum are generally malignant, and produce loss of translucency, followed by erosion of the bony walls of the sinus. Hence it is impossible to differentiate radiographically an empyema from an early neoplasm—i.e. one which has as yet produced no erosion.

The **sphenoidal sinuses** are seen in the lateral view of the skull to occupy the body of the sphenoid bone. (Plate 42, Fig. 1.) In the oblique supero-inferior view they present a translucent area, more or less square in shape and divided into two lateral portions by a bony septum, lying immediately in front of the basilar process. The two sinuses are frequently asymmetrical. (Plate 42, Fig. 1.)

Inflammatory lesions of the sphenoidal sinuses are thought to be of common occurrence by some observers, but the radiographic demonstration of disease is not always easy. Empyema of both sinuses results in a complete loss of translucency, readily recognized in the lateral view. Unilateral empyema requires the supero-inferior view for its recognition, as in this view only can comparison of the opaque with the translucent sinus be effected. Owing to the technical difficulties this view is not always very satisfactory, and it is possible that many minor lesions confined to one sinus escape detection.

Neoplasms invading the sinus from the naso-pharynx produce erosion of the anterior and inferior bony walls, the abnormality being

seen best in the lateral view.   Invasion of the sinuses from the pituitary fossa is described in the succeeding chapter (p. 83).

The mastoid antrum and mastoid air-cells. —A skiagram of the normal mastoid region constantly shows the irregularly-shaped, translucent area of the air-containing antrum, and generally, but not always, a number of cellular spaces in the bone above, behind and below this area. These spaces vary in degree of translucency, the variation depending on their air or their marrow content ; their margins are, however, clearly defined in both instances.   The arrangement, size, number and extent of distribution of these cells present great individual variations.   The air-containing cells are named *pneumatic*, in distinction from the *diploetic* cells with marrow content.

The following types of mastoid structure can be distinguished : *

(1) The *infantile* type of mastoid may be—

    (*a*) Entirely diploetic,

    (*b*) Sclerotic (i.e. devoid of any recognizable cellular structure), or

    (*c*) A combination of infantile and pneumatic type.

The infantile types of mastoid persist throughout life in a considerable percentage of individuals.   These persistent infantile mastoids mostly belong to category (*a*) (diploetic).

(2) The *pneumatic* type of mastoid is regarded as characteristic of later childhood and adult life, although, as previously stated, pneumatic cells may be seen in the first year of life and, on the other hand, many adult mastoids retain the diploetic form of the infantile type The following forms are described :

    (*a*) The pure pneumatic type, in which all the cells are in communication with the mastoid antrum and contain air. The largest cells are found in the lower portions of the mastoid process.

    (*b*) Some of the cells are pneumatic and others diploetic ; the latter occupy the lower portions of the mastoid process.

    (*c*) Another combination of pneumatic and diploetic cells, in which the former lie externally to the latter.

This last form of mastoid structure, however, cannot be differentiated radiographically from the pure pneumatic type.

Inflammatory lesions of the mastoid result in loss of translucency of the pneumatic cells if any be present, together with loss of detail in, and subsequent destruction of, the bony cell-walls.   The diploetic cells show less striking changes as regards translucency, but the changes in the cell-walls can usually be observed.   In the dense, sclerotic type of mastoid no changes are demonstrated other than

* Isaac Serber, *Amer. Journ. of Roent.*, 1919.

those common to inflammatory lesions of bone in all parts of the body. It is important to distinguish a normal sclerotic mastoid from one of pneumatic or diploetic type in which inflammatory changes have occurred; in the latter case it is usually possible to recognize the presence of cellular spaces. Comparison of the two sides must invariably be made when investigating the mastoid; fortunately it is usual for both mastoids to conform to the same type, although this rule is not invariable.

THE CENTRAL NERVOUS SYSTEM

LESIONS of the brain and cord are only directly recognizable in a skiagram if some definite alteration in the opacity to X-radiation occurs in the affected tissues. This is a rare event. A number of lesions, however, provide indirect radiographic evidence of their presence by reason of changes produced in the surrounding bony structures. By means of special procedures, to be described below, it is also possible to make radiographic investigations of the cerebral ventricles.

Lesions of the spinal cord are not accompanied by any recognizable variation in opacity to X-radiation, nor characteristic changes in the bony walls of the spinal canal. Methods of demonstrating the sub-arachnoid space are, however, available, and are of value in some cases.

VARIATION IN OPACITY OF THE CRANIAL CONTENTS

A skiagram of the head of a normal individual gives no indication of the cranial contents, the variations in opacity seen in different parts being representative of the bones of the vault with their structural details.

Increased translucency of a portion of the brain is seen in *pneumatocele cranii*. This rare condition results from fracture involving the frontal sinus, with injury to the underlying frontal lobes and escape of air into these lobes. The skiagram shows an area of great relative translucency in the frontal region, having a well-defined margin and more or less rounded shape. Occasionally the lateral ventricle is opened, and is then outlined over part of its extent, the actual shape of the translucency varying with the quantity of air in the ventricle and the position of the patient's head.

Increased intracranial opacities result from calcification or ossification of various structures. The opacity is usually quite localized and, when due to calcification, punctate in nature. The tissues involved can generally be inferred from the position of the abnormality.

Calcifications of the *falx cerebri* and of the *pineal body* produce opacities which occupy the mid-line in an antero-posterior skiagram. In the lateral view the opacity of the calcified pineal body is seen in

the temporal fossa, 1½–2 inches above the external auditory meatus ; it is small and rounded in both views.   The position of the opacity in the lateral view of a calcified falx necessarily varies with the portion affected.

Calcification of the *choroid plexuses* presents, in the antero-posterior view, opacities symmetrically placed on either side of the mid-line.   In the lateral view the opacity may be above, in front, or below and behind the position of the pineal body.

Symmetrical *retrobregmatic ossification* of the *dura mater* on either side of the longitudinal sinus results in symmetrical sickle-shaped opacities in the antero-posterior view, these opacities being situated to either side of the mid-line below the interparietal suture.*   They may be of some size.

Calcified cysticercus produces multiple, small, dense opacities approximately in the mid-line in an antero-posterior view (O'Sullivan). *Calcified cerebral hæmorrhages* are occasionally seen.

Calcified tumours of the brain are very rare ; they are generally psammomata.   The opacity is usually larger and less clearly defined than in the other conditions noted above (O'Sullivan).

Cranio-pharyngeal pouch tumours arise from Rathke's pouch, forming the anterior lobe of the pituitary.   These tumours become the seat of calcareous deposit, which produces a somewhat delicate spongy opacity situated directly above the sella turcica or over the anterior clinoid processes.   The sella is often deformed.†

Abnormalities of the Skull resulting from Intracranial Lesions

1. **Localized hyperostosis,** or increased thickness of the vault showing normal structure, is not infrequently seen over meningeal and endothelial tumours.

2. **The sella turcica.**—The normal sella turcica presents considerable variation in shape and size in different individuals.   As many as five distinct types of normal sella have been described, but the majority fall into one of three classes, the oval, the round, and the flat.   The majority of sellæ belong to the oval group.   The minimum antero-posterior diameter of the sella may be taken as 0·5 cm. and the maximum as 1·6 cm.   The vertical depth varies from 0·4 cm. to 1·2 cm.   Union between the anterior and posterior clinoid processes is of some frequency and possesses no clinical significance.‡   It must be remembered that considerable technical difficulties are encountered in examination of the sella turcica, and that slight deviations of the

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* O'Sullivan, *Brit. Journ. of Radiol.*, 1915.

† McKenzie and Sosman, *Amer. Journ. of Roent.*, 1924.

‡ Camp, *ibid.*

skull from the true lateral position, or of the vertical ray from the sella itself, will produce gross distortions in the skiagram.

Abnormalities of the sella turcica may be produced by pituitary tumours, or by any lesion which results in longstanding increase in intracranial pressure.

Pituitary tumours produce a uniform circular enlargement of the fossa, the expansion affecting chiefly the posterior and inferior walls. Posteriorly the dorsum sellæ is gradually eroded, becoming at first thinned out, and then disappearing completely ; while inferiorly the floor of the fossa is depressed into the sphenoidal sinuses, and eventually destroyed. This downward expansion produces a characteristic " double line " in the floor of the sella, the upper portion representing the intact lateral margin of the fossa, while the lower portion represents the lower aspect of the tumour, rendered visible in the skiagram by virtue of its contrast with the air in the sphenoidal sinuses. The anterior clinoid processes become shortened, otherwise the anterior margin of the fossa shows little change. Pituitary tumours do not usually cause generalized radiographic changes indicative of increased intracranial pressure, but the prognathous deformity with simple overgrowth of the facial bones typical of acromegaly may sometimes be seen (Camp). (Plate 44, Fig. 3.)

Increased intracranial pressure of long standing results in flattening of the sella from above. The anterior clinoid processes therefore become thinned out instead of diminished in length, the posterior clinoids are shortened rather than thinned, and the fossa is flattened. In this way the depth of the fossa tends to diminish rather than to increase, although in some cases the floor is pushed downwards as with pituitary tumours. When advanced changes have occurred it is impossible to differentiate these two types of sellar deformity from one another (Camp).

3. Generalized changes in the skull resulting from increased intracranial pressure.—In infants the cranium is enlarged, often to a marked extent, and the sutures are increased in width. The bones of the vault show uniform thinning, or the thinning may be greater over the areas affected chiefly by external pressure, but " ribbing " of the skull, due to convolutional impressions, is absent.

In older children, and even in young adults, separation at the cranial sutures may be observed. This is evidence of progressive increase in intracranial pressure, since, with a stationary pressure, rapid new-bone formation obliterates any tendency to opening of the sutures. Jefferson* states that cerebellar tumours and obstructive hydrocephalus of adhesive origin are most frequently responsible for sutural diastasis.

* *Proc. Roy. Soc. of Med.*, 1924.

" *Ribbing* " of the skull occurs in adults as a result of thinning of the cranial bones from convolutional pressure. Ribbing is generally best seen over the frontal lobes, but may occur elsewhere ; as ribbing is seen in a certain number of normal individuals, too much significance must not be attached to this appearance. (Plate 44, Fig. 2.)

Enlargement of the diploetic veins.—In any good skiagram of a normal adult skull a certain number of diploetic veins are demonstrated. Lewald* describes two normal patterns of these veins, although minor individual modifications are invariable :

(*a*) There is a stellate arrangement in the parietal region, one branch continuing into the posterior temporal region and communicating with the lateral sinus through the mastoid emissary vein (Piersol).

(*b*) The stellate appearance is absent ; a large channel and a small one pass back nearly to the lambdoid suture, and then downwards and forwards to the mastoid emissary vein (Spalteholtz).

The latter is the more common formation. In both types there are anterior frontal, anterior and posterior temporal, and occipital diploetic veins on each side.

Radiographically, some portion only of the diploetic venous system is demonstrated in any individual. " Enlargement " of the diploetic veins as seen in the skiagram is only a relative term, indicating that the bony channels containing these veins are more obvious, more numerous in the skiagram, and of greater width, than is usual in the normal subject. Considerable importance has been attached to these appearances in the past, but it is now generally recognized that great individual variations occur in normal adults, including asymmetry in the veins of the two sides of the skull. It would therefore appear that little, if any, importance attaches to these apparent venous dilatations. Plate 44, Fig. 1, shows very well-marked diploetic venous channels in a patient with no evidence of increased intracranial tension.

From the foregoing description it will be seen that unequivocal radiographic evidence of increased pressure is rarely obtained in adult patients.

Examination of the cerebral ventricles.—Radiographic examination after partial removal of fluid from the ventricular system and its replacement by air has been named ventriculography. The inception and development of this method of investigation are due entirely to Dandy.†

The fluid which forms in the lateral ventricles passes backwards in the normal subject through the foramen of Munro to the 3rd ventricle, thence through the aqueduct of Sylvius to the 4th ventricle, and

Fig. 1.—Enlarged diploetic venous spaces.

Fig. 2.—Convolutional ribbing of skull.

Fig. 3.—Expansion of sella turcica due to an int
tumour.

PLATE 44.

finally through the foramina of Luschka and the foramen of Magendie to the cisterna magna ; absorption taking place outside the brain.

Therefore any obstruction will result in dilatation of the ventricular system in front of the lesion.   A blockage at the foramen of Munro results in dilatation of one lateral ventricle, while a blockage of the aqueduct of Sylvius causes dilatation of the 3rd ventricle and both lateral ventricles.   A large number of cases of internal hydrocephalus have been investigated in this way and the site of obstruction demonstrated.

The practical value of this method, however, is chiefly found in the diagnosis and localization of tumours in the silent areas of the brain —i.e. in those regions where no localizing symptoms result from the growth.

Dandy states that all cerebral tumours which cause symptoms of increased intracranial pressure produce changes in shape, size or position in one or more of the ventricles, the majority being recognized by their effect on the lateral ventricles.

The method is attended by a high mortality, and interpretation of the skiagrams is a matter of extreme difficulty.   Moreover, there appear to be possibilities of fallacy even after the most skilled interpretation—for example, œdema, occurring at a distance from the tumour, may result in ventricular deformity indistinguishable from that produced by growth actually pressing into the ventricle.

As a result of these disadvantages the method has been rarely practised in this country.

Diagnosis of hydrocephalus.—In infants the skiagram shows some degree of general enlargement of the cranium, this enlargement being partly accounted for by wide separation of the sutures, partly by increased size of the bones of the vault. There is general thinning of the bones.   In late childhood diastasis is absent owng to rapid ossification around the margins of the bones of the vault, except when the intracranial pressure is progressively increasing.   " Ribbing " of the bones may be seen in late childhood and in adults.   Increased vascularity of the skull, as shown by dilatation of the diploetic veins, is of little positive value.

Internal hydrocephalus cannot be radiographically distinguished from the external form without resort to ventriculography.

Diagnosis of intracranial tumour. — Radiographic signs of cerebral tumour may be classified as local and general.   The *localized* signs are :

(1) Hyperostosis over a meningeal or endothelial tumour.   This is of value when considered with the clinical evidences of this disease ; in itself the hyperostosis presents no characteristic appearances.

(2) Deformity of the pituitary fossa ; this, when of the type

described above as being produced by intrasellar pressure, constitutes conclusive evidence of a pituitary neoplasm.

(3) Calcification in psammomata and in cranio-pharyngeal pouch tumours.

In psammomata the opacity is larger, more irregular, and with less defined margins than is usual in the other intracranial calcifications; while in cranio-pharyngeal pouch tumours the opacity is of spongy or feathery appearance, is situated immediately above the sellar or the anterior clinoid processes, and is usually associated with sellar distortion.

The *general* signs of intracranial tumour are :

(1) Ribbing of the skull.

(2) Enlargement of the diploetic venous channels.

Both these appearances may occur in normal individuals, and their diagnostic value is therefore very slight.

(3) Deformity of the pituitary fossa of the type resulting from general increased intracranial pressure.

(4) Abnormalities in shape, size and position of the cerebral ventricles, as shown by ventriculography.

It will be gathered that the radiographic diagnosis of cerebral tumour is, in the majority of cases, highly speculative, and extreme caution should therefore be exercised in forming any definite opinion. If the intrasellar tumour be excluded, the most that can generally be said is that the appearances are *consistent* with the presence of an intracranial neoplasm.

Diagnosis of spinal-cord tumours.—Tumours of the spinal cord produce no recognizable opacity in the skiagram. Simple scoliosis and kyphosis are sometimes present, and can of course be demonstrated, but are associated with no changes indicative of the underlying lesion.

The *level* of a tumour, whether arising outside the dura, from the inner surface of the dura, or in the cord itself, can be demonstrated by X-ray examination after injection of lipiodol (a thin oily fluid containing 40 per cent. of iodine, extremely opaque to X-radiation, and quite non-irritating to the tissues).

The lipiodol is injected into the subarachnoid space by suboccipital puncture, after withdrawal of a corresponding quantity of cerebro-spinal fluid. The injection is made with the patient in a sitting posture, and this posture is maintained until after the radiographic examination. The opaque fluid, being of high specific gravity, percolates down the subarachnoid space until it is arrested by the pressure of the tumour. The skiagram may show the entire injection maintained at this level, or, if the pressure be comparatively slight, some proportion only of the fluid may remain to indicate the position of the lesion.

By these means the upper border of the tumour is localized. The lower border may then be determined by injection of air into the lower portion of the subarachnoid space, still retaining the patient in the sitting posture. The bubble of air rises to the lower limit of the growth, and is there arrested, appearing in the skiagram as a well-defined translucency.

This latter procedure is not free from objection, but no ill effects have been reported from the lipiodol method.

It is obvious that no information is obtainable in this way as to the nature of the neoplasm; nor can the presence of the lesion be detected until it has attained sufficient size to afford definite obstruction to the passage of the opaque fluid (or air).

In certain cases, moreover, positive findings in the skiagram have not been confirmed at subsequent operation, nor has any explanation been forthcoming to explain the anomaly.

In spite of these limitations and possible sources of error, the lipiodol injection method is of very great value when employed in suitable cases.

THE GENITO-URINARY SYSTEM

THE urinary system is examined by means of routine skiagrams, followed, if necessary, by special methods, some of which demand a preliminary surgical procedure.

The technique of the routine investigation, which, if successfully carried out, suffices in the majority of cases, requires considerable care. An examination which for any reason results in technically poor skiagrams must be repeated, and, if necessary, more than once.

Proper preparation of the patient is the first essential, and should never be omitted except in cases of urgency. The preparation aims at emptying the gastro-intestinal tract to the greatest possible extent without causing gaseous distension of the intestines. With this object a mild aperient is given on the two evenings preceding the examination. Vigorous purgatives, and especially salines, must be rigorously avoided, as likely to produce meteorism. In addition, the patient takes as little food as possible on the day immediately preceding the examination, and abstains from breakfast the following morning, although a small quantity of tea and toast is permissible.

Should the bowels fail to act on the morning of the investigation a colonic wash-out is advisable, but otherwise this is best omitted.

The preliminary examination includes the whole urinary tract. This can be effected by taking two plates, the upper of which, placed on the back, includes both kidneys and the upper portions of the ureters; while the lower, placed either on the back or the abdomen, includes the lower portion of both ureters, the bladder, and the prostatic urethra. Both skiagrams should be symmetrical, the patient lying absolutely flat and straight and the tube being centred in the mid-line; for the upper skiagram the point of centration is the spinous process of the 2nd lumbar vertebra, and for the lower skiagram the upper border of the symphysis pubis. Compression should be applied over the abdomen so as to diminish the thickness of soft tissues and aid in immobilization; the anodal distance, however, must on no account be reduced below 30 cm., and is preferably substantially greater.

Respiration must be entirely suspended during the exposure of

Fig. 1.—Opaque catheter in lower ureter.

Fig. 2.—Calcified glands. Opaque catheter in ureter.

PLATE 45.

the upper plate, and this is also advisable, though not so essential, when exposing the lower plate. The tube should be soft medium ($4\frac{1}{2}$–5 inches parallel spark-gap).

The upper plate, if completely satisfactory, should show the following structures :—

(1) The lumbar spine *with the transverse processes.*

(2) The 11th and 12th ribs.

(3) The posterior part of the iliac crests.

(4) The outer borders of both psoas muscles.

(5) The outlines of both kidneys.

Both plates should be absolutely symmetrical, and be free from the translucencies of intestinal gas or the opacities of food-residue.

It has been recommended that oxygen or carbon dioxide be injected into the perirenal tissues to afford a translucent contrast and thus enable the kidney outline to be more completely demonstrated. The technique of the injection is not easy, and the procedure is not devoid of accidental possibilities. The method would appear to be rarely if ever justified, since with modern apparatus and technique the kidney outline can be shown even in the stoutest patients without such adventitious aid.

The above standardized method of examination possesses one invaluable advantage, in that the relationship of the ureter (if normal) and the base of the bladder to the bony structures is definitely known.

The right ureter commences just external to the tip of the 2nd lumbar transverse process, and passes across the tip of the 3rd transverse process and the inner part of the 5th ; it then descends almost vertically across the inner margin of the sacro-iliac synchondrosis, turns outwards and downwards to pass just internal to the spine of the ischium, and curves inwards to the base of the bladder.

In this curved portion of its course in the pelvis the ureter is separated from the shadow of the pelvic brim by at least $\frac{3}{4}$ inch, this distance gradually increasing as the ureter turns inwards towards the bladder. (Plate 45, Fig. 1.)

The upper end of the left ureter is a little higher than the right, but its course is otherwise identical.

It must be remembered that *developmental abnormalities of one or both ureters* are by no means uncommon. The most frequent abnormality consists in a double ureter ; the reduplicated structures may fuse at any part of their course towards the bladder, or may enter that viscus by two distinct openings.

Displacements of the ureter, in the absence of reduplication, are not common, but sometimes . occur. Developmental abnormalities can only be determined by one of the accessory methods of examination described later.

The position of the bladder in the standardized skiagram necessarily varies with the quantity of its contents, a factor which is not always under the control of the radiologist ; the urethral orifice of the bladder, however, occupies a fairly constant level about $\frac{1}{4}$ inch below the upper border of the symphysis pubis, in the mid-line. The prostatic urethra lies behind the remainder of the symphysis pubis in the male.

Further skiagrams may often be required of one part or another of the urinary tract, with compression differently disposed from that of the routine examination ; but it must be remembered that as soon as the mid-line ceases to be the point of centration the relationship of the urinary structures to the bony parts described above no longer holds good.

Nephroptosis, unless extreme, or complicated by adhesions fixing the kidney, is not demonstrated well in the skiagram, since the compression of the abdomen necessary to obtain a good view of the renal outline generally presses the kidney upwards into its normal position. The upright posture has been suggested during examination for the full elucidation of renal ptosis, but it is only in the thinnest subjects that a satisfactory demonstration can be obtained in this way ; and the same criticism holds good for screen examination, the kidneys rarely being seen on the fluoroscope.

Enlargements of the kidney, if of moderate degree, can be determined from a satisfactory skiagram, bearing in mind the fact that in stout subjects the renal shadow is larger than in those. who are thin, owing to the greater distance between the viscus and the plate.

In great renal enlargement the kidney outline is often difficult to demonstrate, the whole loin showing a uniform increase in opacity as compared with the normal ; the margin of the psoas is sometimes obscured.

Perirenal adhesions are indicated by an irregular ragged kidney outline in place of the normal smooth curved margin. The presence of adhesions is confirmed by noting restriction or loss of the normal renal excursions on respiration ; this is occasionally possible by fluoroscopic examination, but generally necessitates skiagrams taken in full inspiration and expiration.

Inflammatory lesions of the kidney of pyogenic origin may result in enlargement of the kidney outline, or ragged contour due to perirenal adhesions, but otherwise they produce no radiographic abnormality.

In tuberculous infections no evidence of the lesion may be obtained from the skiagram. In other cases, however, the presence of calcified caseous material in an enlarged kidney results in characteristic opacities ; these opacities are commonly large, multiple, of irregular shape

Fig. 1.—Triangular calculus in renal pelvis; smaller calculus in a lower calyx.
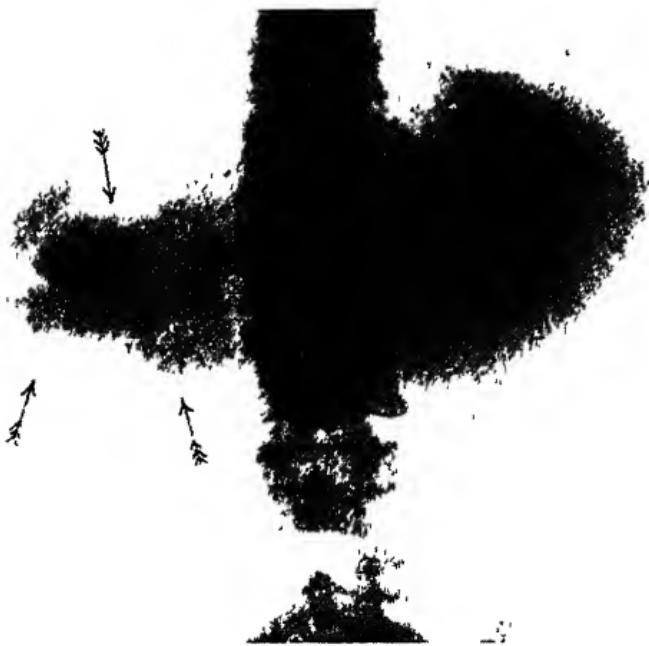
Fig. 2.—Large renal calculi in calyces.

PLATE 46.

and with ill-defined margins. The opacities are not uniform over their whole extent, but show irregular gradations of density. If the kidney outline can be made out, this is seen to be enlarged, often to a great extent, and the opacities are all contained within its borders ; they are most commonly situated towards the lower pole, but in advanced disease may occur through the entire kidney substance, and are then often more or less confluent.

Perirenal suppuration, as a rule, completely obscures the kidney outline and produces a uniform increase in opacity of the loin as compared with the sound side. The lesion cannot be distinguished radiographically from those renal enlargements in which the kidney outline is lost.

Renal tumours are not often recognizable by routine examination, except as an enlargement of the kidney outline by no means pathognomonic of neoplasm.

URINARY CALCULI

The recognition or exclusion of calculi forms by far the most frequent and valuable application of routine radiographic examination. Pure uric-acid calculus is not opaque to X-radiation, or rather its opacity is so slight that it cannot be differentiated from the soft tissues ; all other urinary calculi possess an opacity which is recognizable in the technically perfect skiagram. Cystin calculi are frequently said to be non-opaque, but in point of fact they possess quite a high degree of opacity and are readily demonstrated.

Calculi in the kidney are most frequently situated in the pelvis or the calyces, but may be seen towards the periphery of the renal outline. They are often multiple, and present great variety in shape ; the most common form is the rounded or triangular calculus seen in the pelvis, while large pelvic calculi frequently present prolongations into the calyces. (Plate 46, Figs. 1, 2.)

Renal calculi show a uniform opacity, in the sense that no punctate or granular structure is visible. Large calculi may show a fading-off in density of opacity from the centre to the periphery, representing the variation in thickness of the stone. Lamination is exceedingly rare. The margins of the opacity are smooth and very sharply defined, and no manœuvre succeeds in displacing any part of the shadow beyond the limits of. the renal outline. Slight movement may take place of a small calculus within the limits of the pelvis and calyces.

In lateral views of the lumbar region the shadow of a renal calculus, if it can be made out at all, generally lies over the body of one of the lumbar vertebræ. Occasionally part of the shadow may project in front of the vertebral body when the calculus is large.

Ureteric calculi, if small, are either round or elongated. Large

ureteric calculi are generally elongated, the long axis of the opacity coinciding with the line of the ureter. Ureteric calculi generally present a uniform opacity, the margins of which are regular and clearly defined. The opacity cannot be displaced from the position occupied by the ureter, when this is normal. Ureteric calculi, while generally small, may attain a length of as much as 6 inches; these large calculi are more common in the lower part of the ureter. (Plate 47, Fig. 1.)

Vesical calculi are more often single than multiple. When recently passed from the ureter the calculus is rounded or elongated in shape, but the calculus which has formed in the bladder or been retained there over a considerable period is characteristically rounded or oval. The opacity is often uniform and always (like other urinary calculi) devoid of any punctate structure, but lamination is by no means uncommon. (Plate 47, Fig. 2.) Vesical calculi often attain a considerable size; they are mobile within the limits of the bladder unless encysted.

Calculi in the prostatic urethra are necessarily of no great size, although an impacted calculus may show an expanded upper extremity lying in the bladder. The opacity is seen behind the symphysis pubis exactly in the mid-line.

Prostatic calculi are small, irregular in shape, and nearly always multiple. They are seen as uniform opacities with clearly defined margins behind the bodies of the pubic bones on either side of the symphysis. (Plate 47, Fig 3.)

Differential diagnosis.—The opacities produced by urinary calculi must be differentiated from other opacities in the abdomen. These may be produced by—

    (1) Gall-stones.
    (2) Pancreatic calculi.
    (3) Calcified glands.
    (4) Phleboliths.
    (5) Calcified caseous material in the kidney.
    (6) Intestinal contents.
    (7) Appendicular concretions.

(1) **Gall-stones.** — The characteristic appearance of biliary calculus is a ring shadow—i.e. an opacity with round or irregularly angular outlines, surrounding a central translucent area. This is due to deposition of opaque salts upon the surface of a non-opaque cholesterian stone. These opacities are frequently multiple, and they may be obviously faceted. (*See* Plate 78, Fig. 1, facing p. 208.)

In the routine skiagram they occupy the right renal area and sometimes the loin below and external to the lower pole of the kidney, in which latter case the diagnosis is at once established. The pear-shaped

Fig. 1.—Ureteric calculus.

Fig. 2.—Vesical calculus.

Fig. 3.—Prostatic calculi.

PLATE 47.

opacity of an enlarged gall-bladder may also be demonstrated, containing the calculi within its margins. Calculi in the gall-bladder are seen in front of the vertebral column in a lateral view of the abdomen.

Biliary calculi occasionally present a uniform opacity, generally rounded and single. If situated in the gall-bladder a lateral view establishes the diagnosis, but if in the bile-ducts the resemblance to renal calculus is exceedingly close, and the passage of an opaque catheter (*see* below) is necessary to differentiate the lesions.

(2) Pancreatic calculi usually occupy the head of the pancreas, and are then internal to the upper end of the ureter, while the long axis is transverse to that of the ureter. The passage of an opaque catheter may be necessary to confirm the diagnosis.

(3) Calcified abdominal glands form much the most frequent source of difficulty and error in examinations of the urinary tract. Calcified glands are generally multiple ; attention must be directed towards (a) the nature of the individual opacities, (b) the position of the opacities, and (c) their mobility.

(a) The common opacity produced by a calcified gland is not uniform over its whole extent, but irregular, and generally quite definitely punctate or granular. The outline is irregular and the margins are often ill defined. Occasionally complete calcification of a gland results in a uniform rounded opacity.

(b) Some of the opacities may correspond in the routine skiagram to the position of the urinary structures, but others will generally be seen lying outside the renal and ureteric areas. Since, however, urinary calculi may coexist with calcified glands, an attempt must be made to displace all the shadows beyond the limits of the urinary structures in subsequent skiagrams by applying compression directly over the suspected opacity.

(c) Calcified glands are generally situated towards the intestinal attachment of the mesentery, and hence enjoy a wide range of mobility. As a result, it is generally found that the position and relation to one another of the shadows is inconstant in repeated skiagrams if suitable compression is applied, and, as stated above, displacement completely outside the limits of the urinary structures is often possible. (Plate 45, Fig. 2.)

(4) Phleboliths are very common in the pelvis. They present small round uniform opacities and are generally multiple. The common positions are—

(a) In the region of the ischial spine. A group of the opacities is generally seen, not disposed in the line of the ureter. A single opacity will require an opaque catheter for definite elucidation, although the very small size is suggestive of the true causation.

(*b*) One or more phleboliths are often seen immediately above the antero-external portion of the pelvic brim. These are larger than the opacities in groups (*a*) or (*c*), with which they may be combined. They lie below and external to the line of the ureter.

(*c*) Multiple phleboliths are common in the prostatic plexus, and are seen behind the bodies of the pubic bones. Some may occupy the position of prostatic calculi, but others will be observed at a greater distance from the mid-line. The opacities are, moreover, more widely separated and irregularly disposed than those of prostatic calculi.

(5) **Calcified caseous material** in a tuberculous kidney has already been noted. The opacities are large, ill defined, and irregular in density, shape and outline.

(6) **Intestinal contents** produce ill-defined irregular opacities of varying density and mobility. They are frequently surrounded by a zone of translucency resulting from intestinal gas. The presence of these shadows indicates a failure to secure proper preparation, and in cases of doubt a re-examination must be made after the necessary steps have been taken.

(7) **Appendicular concretions** sometimes become calcified, and then produce elongated, fairly uniform opacities of date-stone shape. Usually the position of the shadow outside the limits of the urinary structures suffices to exclude calculus. Should the concretion chance to lie in the line of the ureter, an attempt must be made to displace it from this position by suitable compression ; failing this, resort must be had to the opaque catheter.

Value of the opaque catheter.—The passage of a ureteric catheter made of some substance opaque to X-radiation may be of great service in determining the nature of a doubtful opacity in the pelvis or loin. Should the shadow of the catheter be contiguous with that of the supposed calculus, a second view should be taken from a different angle to confirm the actual juxtaposition of the shadows. It must be remembered that the catheter will represent one division only of a double ureter, and should the bifurcation not extend to the bladder the presence of this abnormality will not be indicated by opaque catheterization. This may result in erroneous conclusions being drawn from the examination, since a calculus may lie in that division of the double ureter which is not visualized by the catheter. (Plate 45, Fig. 2.)

PYELOGRAPHY

The passage of an opaque ureteric catheter and subsequent injection of an opaque fluid into the pelvis of the kidney enable a skiagram to be obtained of the renal pelvis and calyces.

The opaque fluids in common use for this purpose are sodium bromide (30 per cent.) and collargol (7 per cent.), the former possessing

some advantage in being less irritating to the renal tissue than the latter.

Should a general anæsthetic be necessary for the catheterization, the patient must be allowed to recover from this before injection of the pelvis, as it is essential that the breath be held during the exposure of the X-ray plate.

Recognition of gross abnormalities of the pelvis and calyces is easy ; but interpretation of the skiagram in the early stages of disease is fraught with difficulties, owing to the variability of the normal appearances. For this reason it is always advisable to inject both kidneys, as there is a strong tendency for the pelvis on the two sides to conform to the same type.

The normal pyelogram. — The renal *pelvis* is usually pyramidal in shape, with slightly curved upper and lower borders, the apex of the pyramid being directed towards the ureter. There is no recognizable point of demarcation between pelvis and ureter, the one merging gradually into the other. A curve is described by the lower margins of the upper end of the ureter, the pelvis, and the inferior major calyx, which approximates to a semicircle.* The ureteric catheter usually enters the superior major calyx. The normal pelvis may not, however, conform at all closely to the normal pyramidal shape, but may tend to be spherical or square, or long and tubular.† Occasionally, also, the pelvis is oval or rounded, and receives the minor calyces direct, the major calyces being absent.‡

The *calyces* are divided into major and minor. The major calyces are usually two in number, a superior calyx directed upwards and outwards, and an inferior calyx directed downwards and outwards. A median major calyx is sometimes described, but appears to belong usually to the minor group. The minor calyces spring from the peripheral portions of each major calyx ; they are variable in number. Both major and minor calyces tend to be somewhat pyramidal in shape, the bases being directed towards the periphery of the kidney. The free extremities of the minor calyces, however, are definitely expanded and present a well-marked indentation or cup, but this is only apparent if the calyx is seen in profile—if viewed in any other plane the outline is rounded or oval. (Plate 48, Fig. 1.) The minor calyces may open directly into the pelvis, as stated above ; in other instances the major calyces unite just above the ureter, the pelvis being practically absent.

In *double kidney* the cleavage into the superior and inferior major

* Thomson-Walker, *Arch. of Radiol.*, 1923, xxvii. 334–43.
† Nichols, *Amer. Journ. of Roent.*, N.S., 1924, xi. 25–35.
‡ Beeler and Mertz, *ibid.*, 1924.

calyces is continued through the pelvis, and may also affect the ureter for any distance. In examples of double kidney the lower of the two pelves is usually the larger and occupies the position of the normal renal pelvis. The relation of the injected upper or lower pelvis to the kidney outline when only one is visualized, and the disposition of the calyces, usually suffice to indicate this anatomical abnormality.

Capacity of the pelvis.—The quantity of fluid which can be injected into the pelvis and calyces of the kidney with the production of only slight discomfort is known as the " capacity of the pelvis." This varies greatly in normal individuals, but is usually between 10 and 15 c.c. A capacity of 25 c.c. or over usually indicates hydronephrosis. The capacity of the pelvis itself is commonly greater than that of the calyces combined, but may be much less ; the total capacity is generally the same on the two sides. A normal pelvis which has been over-distended tends to become rounded, and must be distinguished from a hydronephrotic pelvis (*see* below). Sometimes the ureter dilates under pressure, and may then show kinking, and this must be disregarded if the pelvis and calyces show no abnormality.

The abnormal pyelogram.—Pyelography is of great value in the diagnosis of hydronephrosis, and also in a certain proportion of inflammatory and neoplastic lesions. It is necessary, however, to emphasize the difficulties of correct interpretation and the advisability of examining both kidneys.

Hydronephrosis.—The earliest changes are observed in the minor calyces, the extremities of which become rounded and expanded, with loss of the normal indentation or " cup." At the same time the margins of these parts show loss of definition ; the necks of the minor calyces then become diminished in length but increased in breadth, and the bases of the major calyces also show an increase in breadth. Some enlargement of the pelvis is next observed, and eventually this may become excessive ; the shape of the pelvis alters as dilatation proceeds, tending to become square, but with somewhat convex borders. When this stage is reached the minor calyces will often be found to have disappeared while the major calyces are enlarged throughout their whole extent.

The uretero-pelvic junction undergoes characteristic changes in well-marked hydronephrosis. The pelvic dilatation first results in a definite point of demarcation between the pelvis and ureter, and a distinct angle is formed at the junction. As dilatation of the pelvis advances, this angle becomes more acute, and finally is obliterated in the skiagram owing to the shadow of the lower part of the pelvis blending with that of the upper end of the ureter. (Plate 48, Figs. 2, 3.) Kinking of the upper end of the ureter, with signs of *early* hydronephrosis, is strongly suggestive of an aberrant branch of the renal

Fig. 1.—Pyelogram of normal pelvis and calyces.
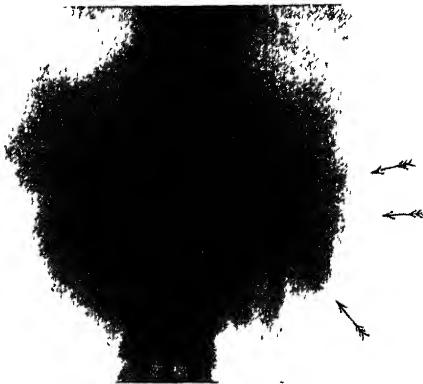
Fig. 2.—Pyelogram of hydronephrosis.

Fig. 3.—Pyelogram of hydronephrosis.

Fig. 4.—Vesical diverticula.

PLATE 48.

Fig. 1.—Congenital dislocation of hip.

Fig. 2.—Reduced congenital dislocation of hip.

Fig. 3.—Bilateral developmental multinucleation of patellæ.

PLATE 7.

artery. A *fully-developed* hydronephrosis due to this cause presents no distinctive features.

The greatest value of pyelography lies in the recognition of the earlier stages of hydronephrosis, before these gross changes have occurred in the pelvis.

Inflammatory lesions. — Pyogenic and Bacillus coli infections only present the changes characteristic of hydronephrosis if they are associated with some obstruction either predisposing to the infection or resulting from the inflammatory condition.

Tuberculous infections are often associated with dilatation and irregular, ill-defined outline of the pelvis and calyces. On the other hand, a small round pelvis surrounded by rounded opacities like a bunch of grapes may be seen in advanced renal tuberculosis. In cortical infections the pelvis is often small and irregular throughout.

Neoplasms.—Papilloma of the pelvis produces an irregular pelvic filling-defect, the tumour mass being outlined by the surrounding opaque fluid. Secondary hydronephrotic changes may be observed indicating obstruction by the growth.

Carcinoma and sarcoma result in extensive changes in the calyces, these becoming deformed, defective and ragged in outline. In *hypernephroma* the calyces also become deformed, but are usually smooth in outline ; the characteristic pyelogram shows great reduction in width of the calyces, constituting the aptly-named " spider-pelvis," but this type of deformity is by no means invariable.

Vesical diverticula can usually be visualized radiographically after injection of some opaque fluid such as sodium bromide (30 per cent.) into the bladder. The diverticula are then seen as rounded projections, sometimes of considerable size, continuous by means of a narrow neck with the bladder opacity. It is advisable to obtain skiagrams at various stages of distension of the bladder, as a diverticulum which is obscured by the shadow of the fully-distended viscus may thus be recognized. (Plate 48, Fig. 4.)

The Uterus and Adnexa

The surface outlines of the ovaries, Fallopian tubes, and intraperitoneal portion of the uterus can be demonstrated after inflation of the peritoneal cavity with oxygen. This process is described in Chapter XVIII.

The lumen of the uterus and tubes can be investigated after injection of lipiodol. The method has been employed chiefly as a means of determining the patency or occlusion of the tubes, the lipiodol passing out of the uterine cavity along the whole length of the tubes and into the peritoneal cavity in the normal individual ; in the case of occlusion the lipiodol is, of course, held up at the point of obstruction.

H

A number of successful examinations have been reported, but the procedure does not appear to be entirely free from risk.

Another method of determining the patency of the tubes consists in placing some gas-forming substance in the cervical canal and attempting to demonstrate the liberated translucent gas in the tubes and peritoneal cavity. In the author's experience this is not very successful, owing to the difficulty in recognizing the small quantity of gas liberated and distinguishing this from possible gaseous contents of the intestines.

Roberts* describes a method of insufflation with air, the patient being in the sitting posture ; patency of the tubes results in slight separation of the liver from the diaphragm by the air which has entered the general peritoneal cavity. This means of diagnosis would appear to be neither so certain nor so free from objection as the lipiodol method.

THE VESICULÆ SEMINALES

The seminal vesicles can be examined after injection of lipiodol into the common ejaculatory ducts ; strictures and dilatations can thus be demonstrated. The process of injection is, as may be imagined, by no means easy, and the practical value of the method has hardly as yet been conclusively proved.

* *Brit. Med. Journ.,* 1925.

HABITUS

THE shape, position and size of the thoracic and abdominal viscera display marked variations in different individuals, but conform fairly closely to average standards in normal subjects of the same build or habitus. Hence it is meaningless to speak, for example, of the normal position of the stomach or the normal shape of the heart, without a qualifying addition as to the habitus of the individual, since a description which is normal for one type would be grossly abnormal for another.

Four main types of habitus can be recognized—(1) the asthenic, (2) the hyposthenic, (3) the sthenic and (4) the hypersthenic.

Each type merges gradually into those next in the scale of gradation, so that many subjects will be found whose characteristics place them midway between two categories. With this reservation the following description will be found generally accurate.

(1) In the **asthenic type** the average body-weight is 45·5 kilogrammes.* The thorax is long in proportion to the height of the subject, and in proportion to its antero-posterior and transverse diameters. It is also noticeably flattened antero-posteriorly. The ribs slope sharply downwards, and the subcostal angle is very acute.

The lungs are seen to be relatively broad above with large apices reaching well above the clavicles, and narrow below; the domes of the diaphragm are flattened, and lie at the level of the 11th rib.

Forced respiration results in a diaphragmatic movement from the position of rest which is much less in inspiration than in expiration, the relative movements being given as 1 : 5. The heart is long and narrow, and the cardio-vascular angle (i.e. the angle formed at the left margin of the cardio-vascular opacity by the junction of the aortic and pulmonary artery outlines) approximates to 180° (Hirsch), and can therefore hardly be recognized.

The obliquity of the cardiac axis = 48° (Mills). (The obliquity of the cardiac axis represents the angle subtended by the junction of the transverse and long diameters of the heart, the long diameter

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* Mills, quoted by Hirsch, *Arch. of Radiol.*, 1921, **xxvi.** 10–19.

extending from the most prominent point on the apex to the right
border at the junction of the auricle and aorta.)

The apex is pointed, and is directed almost entirely downwards.

The abdomen is short and narrow, and shows a marked relative
antero-posterior flattening in its upper part. The lower abdomen
frequently bulges forwards.

The greatest transverse diameter of the pelvis is much greater than
the corresponding diameter of the base of the thorax.

The obliquity of the inferior border of the liver is considerable,
corresponding with the sharply sloping subcostal margin ; the greatest
vertical depth (at the right margin) is increased relatively to the
width. The stomach is long and of exaggerated fish-hook shape,
and descends deeply in the abdomen, the lowest point of the lesser
curvature lying below the highest level of the iliac crests. The stomach
contents tend to gravitate towards the lower pole of the viscus. The
larger part of the small intestine occupies the lower abdomen, and
the colonic flexures are also low. The ascending colon is often long, and
the cæcum lies in the true pelvis. The transverse colon forms a long
loop which descends deeply into the pelvis.

(2) In the **hyposthenic type** the average body-weight is 57·8
kilogrammes (Mills). The relative length of the thorax is less than
in the preceding type, and the transverse diameter is increased. The
ribs do not slope so steeply, the subcostal angle being about 40°. The
bases of the lungs are wider, but still constricted transversely in relation
to the upper parts of the pulmonic fields. The domes of the diaphragm
are somewhat flattened, but slope downwards and lie at the level of
the 10th rib. The relation of inspiratory to expiratory diaphragmatic
movement on forced respiration is as 1 : 3 (Hirsch). The heart tends
to be circular in shape, with a cardio-vascular angle of about 165°
and an axis obliquity of 43°. The slightly rounded apex is
directed downwards and outwards. The abdomen still tends to
the asthenic formation, but in a minor degree. The transverse
diameter of the pelvis is slightly greater than that of the base
of the thorax. The stomach is long, and the lowest point of the
lesser curvature lies about the level of the iliac crests. The trans-
verse colon is long and descends deeply into the pelvis, and the
hepatic flexure is low.

(3) In the **sthenic type** the average body-weight is 68 kilogrammes
(Mills). The thorax is shorter and broader, and the antero-posterior
diameter is considerably increased. The lungs are wider at the base
than in the upper zone of the thorax, and the apices are comparatively
small and project but little above the clavicles. The subcostal angle
is greatly increased, measuring about 90°. The diaphragm shows
an even convexity on either side, and the domes lie at the level of

the 9th rib. The inspiratory and expiratory movements of the diaphragm on forced respiration are as 1 : 2.

The heart is triangular, with a cardio-vascular angle of 150° and an axis obliquity of 37°. The outlines of the right auricle and left ventricle are moderately convex. The abdomen is longer and broader, and the anterior surface is flat or shows a slight general convexity. The transverse diameter of the pelvis is about equal to that of the base of the thorax.

The stomach is only of moderate length, though still of fish-hook shape, and the lowest point on the lesser curvature lies $\frac{1}{2}$–$1\frac{1}{2}$ inches above the iliac crests.

The transverse colon is usually much shorter, and the cæcum seldom descends into the true pelvis. The position of the colon, however, varies greatly in apparently normal individuals of all types.

(4) In the **hypersthenic type** the average body-weight is 72 kilogrammes (Mills). The thorax is short, and the antero-posterior and transverse diameters are relatively great, both reaching their maximum at the thoracic base. The ribs tend to be horizontal in direction. The lungs are very broad at the bases, and relatively narrow in the upper zone, while the apices can hardly be seen above the clavicles. The domes of the diaphragm lie at the level of the 8th rib and are convex. The inspiratory and expiratory excursions of the diaphragm on forced respiration are equal. The subcostal angle is very wide.

The long diameter of the heart is short relatively to the transverse diameter, and the shape tends to be oval. The cardio-vascular angle is 135° and the axis obliquity 33°. The left border of the heart is markedly convex, and the apex forms a wide curve directed outwards.

The abdomen is greater in the antero-posterior than in the transverse diameter, even in those without excess of adipose tissue, and in such subjects is most prominent above the umbilicus. The transverse diameter of the pelvis is less than that of the base of the thorax.

The stomach lies high in the abdomen, being situated entirely above the umbilicus. The long axis is almost transverse, and the fish-hook shape is lost, the lesser curvature sloping continuously downwards to the pylorus. The entire viscus shows a progressive diminution in width between the curvatures from the cardiac to the pyloric poles.

The transverse colon is short, showing only a slight downward convexity. The splenic flexure lies high up under the costal margin, but the position of the hepatic flexure is exceedingly variable.

It is not suggested that every examination of the thorax and abdomen should elucidate all the details enumerated above ; but it is essential to form a broad conception of types, so that each patient may be relegated to his proper category as regards habitus.

EXAMINATION OF THE RESPIRATORY TRACT

THE upper respiratory tract is chiefly of interest to the radiologist in virtue of the accessory nasal sinuses, which have already been considered in Chapter VII.

The **nasal fossæ** are seen in a postero-anterior skiagram as a somewhat pear-shaped translucency, with the broad end below. This translucency is divided by the opacity of the septum, deviations of which can be recognized ; and is bounded on either side by the lateral walls of the fossæ. Projecting into this translucent area are seen the inferior and middle turbinate bones, with their covering mucous membrane, forming rather dense opacities. Enlargements of the turbinates are plainly apparent. Malignant neoplasms in the nasal fossæ (usually growing from the roof or naso-pharynx) cause first displacement and, later, erosion of the surrounding bony structures.

The larynx and trachea.—The lumen of these structures is normally outlined to some extent by the contained air ; that of the larynx is visible as an irregularly shaped translucency continuous above with the translucent pharynx, best seen in a lateral view of the neck. The trachea also produces a band of translucency in the neck, and displacements and flattening from pressure can be determined. In the thorax the trachea is seen as a faint translucency in the antero-posterior view, and becomes much more obvious if displaced to one or the other side of the mid-line, so as to be no longer completely overshadowed by the opacities of the spine and great vessels. The recognition of lateral tracheal displacements in the thorax is of great importance.

The walls of the larynx and trachea produce in young subjects no opacity distinct from that of the surrounding soft tissues. Calcification in the laryngeal cartilages occurs at a variable age, but is often considerable in quite young adults. Extensive calcification produces somewhat ill-defined spotty opacities, which in the lateral view give a fairly accurate delineation of the cartilages ; in the antero-posterior view, however, these shadows, with that of the hyoid bone, can readily be mistaken for some abnormality of the cervical spine.

The **right** and **left bronchi** can be distinguished, under

favourable circumstances, as short bands of translucency passing from the lower end of the trachea to the hila of the lungs.

The lungs and mediastina. Method of examination. —The fluorescent screen plays an essential part in examination of the thorax, but one or more skiagrams must always be obtained as well. The patient is preferably examined in both the horizontal and upright positions, the latter being the more valuable as a general rule.

A general screen examination is first made of the whole thorax in the postero-anterior plane, and reveals gross abnormalities such as large opacities in the lungs or mediastina, or considerable cardiac displacement. The diaphragm is then shut down to a horizontal slit about 1 inch in depth, and wide enough to extend across the whole of both pulmonic fields. Starting at the extreme apices, the area of illumination is gradually carried down to the base of the thorax, finally including both leaves of the diaphragm and the costo-phrenic angles. In this way any marked inequality of translucency in the corresponding portions of both lungs is recognized, and the diaphragmatic position and movements are noted. Forced respiration is demanded during this examination. Some stress has been laid on " lighting-up "—i.e. increased translucency of the normal tissues on full inspiration. While lighting-up is occasionally apparent, the author has frequently failed to discern any variation of translucency on respiration in subjects whose skiagram has revealed no pulmonary abnormality, and he therefore attaches no importance to this sign. Forced respiration is demanded during fluoroscopy for the purpose of investigating the movements of the diaphragm and thoracic wall and demonstrating the presence of mediastinal excursions.

The illumination of the screen is next converted into a vertical band about 6 inches in width, and a survey is made of the mediastina. Detailed examination of the heart and great vessels is described in a later chapter, and it will be sufficient in this place to note obvious enlargements or displacements of the heart and great vessels, having due regard to the habitus of the patient. Adventitious shadows on either side of the cardiac opacity are of especial importance, and an attempt must be made to determine the continuity or otherwise of these shadows with the mediastinal contents. Opacities in the mediastina generally exhibit referred pulsation ; *expansile* pulsation may be demonstrated by cutting down the area of illumination nearly to the margins of the abnormal opacity, but the appearances in this respect are often exceedingly deceptive.

The patient is next rotated into the " first oblique " position— i.e. he takes a quarter turn to the left, the right shoulder thus coming forwards. The posterior mediastinum is now seen as a relatively

translucent zone in front of the dorsal spine, and behind the opacity of the heart and great vessels.

Finally, one or more skiagrams are obtained in the postero-anterior plane, the breath being held in full inspiration during the exposure. Skiagrams may sometimes be advisable also in the first oblique and full lateral positions.

Normal appearances of the lungs. — The normal lung shows translucency over its whole extent, this translucency being modified over a large area by linear and reticular opacities which constitute the " normal lung markings." Further modification occurs at the hilum.

It must be remembered that the hilar shadows and lung markings show great variation in apparently normal individuals ; in fact, it can be safely asserted that, however many skiagrams be examined, no two will be exactly similar.

The term " normal appearances " therefore simply indicates the absence of any variation definitely referable to a pathological process, either old or recent. It is well to point out also that where such variations are quantitative rather than qualitative the greatest care must be taken before deciding that the very elastic boundaries of normality have been overstepped. Many persons in the past have been branded with the stigma of pulmonary tuberculosis on X-ray evidence which we now know to be entirely inconclusive ; and this is only one instance out of many in which our interpretation may be gravely at fault.

In all fields of radiology intimate correlation of clinical and radiographic features is highly desirable ; in investigations of the thorax it is absolutely essential.

The *hilum* produces a rather dense shadow, not uniform over its whole extent. In shape this shadow tends to have a convex outer border, very irregular and ill defined in outline ; the inner aspect of the hilum shadow is applied to that of the cardia, but is quite definitely distinguishable from it. The hilum shadow is confined entirely to the hilar zone of the lung, according to Dunham's division of the pulmonic field, described below. Extension of the opacity upwards or (especially) downwards is of little moment, but extension outwards into the mid-zone of the pulmonic field must be regarded as abnormal.

The varied opacities which together make up the hilum shadow are produced by—

(1) Bronchial lymphatic glands and large lymphatic trunks.
(2) The right or left bronchus with its main divisions.
(3) The right or left pulmonary artery and vein and their main divisions.
(4) Interstitial connective tissue.

The bronchial glands alone can be differentiated with any degree of certainty, as irregularly rounded opacities. Their number, size and degree of opacity vary greatly in apparently normal individuals. Calcification in one or more of the glands is often present, and produces a small round shadow clearly distinguished from the surrounding tissues by reason of its much greater density. A large hilar shadow is quite frequently seen in children, although the *average* relative size is greater in adult life. Oval or rounded ring opacities with trans-lucent centres are often observed towards the periphery of the hilum, and represent divisions of the bronchus seen more or less in section.

From the hilum radiate a great number of branching *linear striæ* which extend into every part of the lung except the apex and the extreme costal periphery. These striæ diminish in width in their outward course, until they become imperceptible. In the hilar zone they commonly show small nodular thickenings (or " nodal points "), but these are normally much less conspicuous in the mid- and peripheral zones of the lung. The striæ extend to the extreme base in the hilar zone and often in the mid-zone.

The lung tissue in the interstices of this branching striate pattern does not show a uniform translucency, but presents an irregular, fine, ill-defined variation known as the normal " lung mottling."

The linear striæ of the lung have been variously attributed to— (1) the walls of the bronchial tree, (2) the blood-vessels, especially the arteries, (3) the lymphatics. It appears probable that the blood-vessels are largely responsible for these striæ in the normal individual, the ramifications of the finest divisions producing the small irregular variations in translucency known as normal lung mottling. Thickening of the lymphatic and bronchial walls, however, must play the most prominent part in the increased striation which results from active or old pulmonary disease.

Overend* gives the following anatomical description of arterial and lymphatic distribution :

The right pulmonary artery passes outwards to just below the level of the eparterial bronchus, where it gives two branches which follow the bronchus and supply the paravertebral, midclavicular, and axillary areas, and two branches which pass out laterally towards the chest-wall below the deep axillary area. The main trunk of the pulmonary artery passes through the hilum outside the main bronchus, and at the level of the anterior extremity of the 5th rib breaks up into branches : one branch is distributed to the middle lobe, one passes towards the costo-phrenic sulcus, and several descend to the middle of the diaphragm ; one of these usually turns inwards towards the right auricle and cardio-phrenic sulcus.

* *Arch. of Radiol.*, 1923, xxvii. 268–76.

The left pulmonary artery runs outwards in front of the left bronchus, describing a curve convex upwards. From the convexity of this curve branches are given off to the upper lobe. The main trunk then breaks up into lateral and descending branches.

The lymphatic system is divided into (1) a superficial network below the pleura ; (2) deep lymphatics accompanying the veins, arteries and bronchi ; (3) small accumulations of lymphoid tissue in the bifurcations of the vessels and bronchi.

It will be found useful and interesting to correlate this anatomical description of the vessels and lymphatics with the radiographic appearances.

Dunham's division of the pulmonic field into zones, referred to on p. 104, is effected as follows :

The apical zone lies above the lower border of the clavicle. Two arcs of a sphere extending from the clavicle to the diaphragm separate the remainder of the lung into an inner, hilar zone, a mid-zone, and an outer, peripheral zone.

The hilar and mid- zones are of approximately equal width, and are slightly wider than the peripheral zone.

. The apical zone in the normal individual is quite devoid of any markings, as is the extreme outer part of the peripheral zone.

The hilar zone contains the hilum, with the main division of the bronchial tree. These main divisions pass into the mid-zone, where they break up into smaller branches.

The twigs of the bronchial tree are seen entirely in the peripheral zone.

It must be borne in mind that this division of the pulmonic field is effected by arcs of *spheres*, and that in any one view of the thorax the zones are superimposed upon each other except as regards the apical area and that portion of the peripheral zone which is seen in profile.

The immediate value of the division is the determination of freedom from any lung markings in the apex, and the restriction of the hilar shadow to the innermost zone.

The diaphragm.—The shape and position of the diaphragmatic domes show wide variations in accordance with the habitus of the individual, as described in the preceding chapter. In general, however, it may be stated that the left leaf of the diaphragm reaches a level $\frac{1}{2}$-$1\frac{1}{2}$ inches higher than the right, and that the outlines of the domes are smooth and regular in every phase of the respiratory cycle. The position and shape of the left leaf of the diaphragm are also subject to transient modifications dependent upon the condition of the stomach and intestines—especially the splenic flexure ; distension of these parts, with either solid or gaseous contents, may result in temporary elevation of the left diaphragm.

Pathological displacements of the diaphragm may occur both in intrathoracic and subphrenic disease. The greatest degree of displacement is seen in paralysis of the phrenic nerve and eventration of the diaphragm, described below.

The shape of the diaphragm may be modified by pressure from below (e.g. hepatic tumour or subphrenic effusion), or by traction from above (e.g. pleuro-diaphragmatic adhesions). "Tenting" of the diaphragm, or angular deformity accentuated on inspiration, is usually ascribed to such adhesions, but Metson* suggests that in some cases this is due to dimpling of the lung on inspiration from infiltration around, or fibrosis of, one of the lower bronchi, with resultant loss of elasticity in the pulmonary tissues.

Flattening of the right dome of the diaphragm by pressure from above can hardly occur to any extent, since this leaf is moulded upon the liver; flattening of the left dome can take place more readily owing to the elastic nature of the air-filled gastric cardia, but in point of fact such flattening is rarely very marked. This can still be demonstrated when the upper aspect of the diaphragm is obscured—e.g. by a pleural effusion—since the lower surface is outlined by the air in the upper pole of the stomach.

The normal excursion of the diaphragmatic domes on quiet respiration is about $\frac{1}{2}$ inch, and on forced respiration from 2 to $2\frac{1}{2}$ inches. As stated in the preceding chapter, the relationship of inspiratory to expiratory excursion varies with the habitus of the subject.

The descent and ascent of the diaphragm normally show a regular progression, with a brief period of immobility at the end of the ascent (i.e. between each expiration and the succeeding inspiration).

In the high, convex dome of the hypersthenic subject, contraction results in flattening of the dome and general descent; the central portion of the dome shows the maximum excursion, and the direction of movement in this part is vertically downwards. In the sloping diaphragm of the hyposthenic the movement is more noticeable in the outer part of the diaphragmatic leaf, and the direction is downwards and inwards in that portion which shows the maximum excursion.

Irregular or *jerky* movements of the diaphragm are sometimes observed in pulmonary lesions, but are of no particular significance if unaccompanied by other evidence of abnormality.

Diminution or *total arrest* of the movements of the diaphragm is seen in inflammatory lesions situated either above or below this structure, and after severe traumatism of the thorax. It is by no means uncommon for the diaphragm to be obscured by an abnormal basal opacity, in which case it may be impossible to determine the presence or absence of movement.

* *Amer. Journ. of Med. Sci.*, 1922.

Inverted movement of one leaf of the diaphragm occurs in unilateral phrenic paralysis and in eventration ; in these conditions the affected leaf is inert, but is further elevated on inspiration by the increased intra-abdominal pressure, the reverse movement taking place on expiration. In this way the two leaves of the diaphragm are seen to move in opposite directions during both phases of the respiratory cycle.

The phenomenon known as Kienbock's " paradoxical movement of the diaphragm " is not apparently associated with any abnormality of the diaphragmatic contractions, and is described later (*see* under Respiratory Excursion of the Mediastinum, p. 135).

INFLAMMATORY LESIONS OF THE PLEURA AND LUNGS

Pleural thickening produces a somewhat irregular opacity which obscures, to a greater or less extent, the markings in the underlying lung. The lesion may occur in any part, but is most commonly seen at the base, in which case the diaphragm is rendered less plainly visible, but is not completely obscured. The margins of the opacity, except where these are formed by the chest-wall or diaphragm, are generally ill defined. A pleural effusion of small size may be completely obscured by surrounding pleural thickening. In very old extensive pleural thickening where a thick layer of fibrous tissue replaces the pleural membranes, such as is not infrequently seen around the apex, the opacity possesses a uniform density and a clearly demarcated free margin.

Increase in the striate markings of the adjacent lung is commonly seen in this latter condition, and sometimes a definite collapse of the chest-wall as compared with the unaffected side.

Pleural effusion may be *parietal, mediastinal,* or *interlobar.*

The parietal effusion produces a dense uniform opacity with very clearly defined margins; it may be localized by adhesions to any part of the parietal pleuræ, but in the absence of such limitation is first seen as a triangular shadow filling up and obliterating the costo-phrenic angle. A small effusion in this situation presents a free mesial border, slightly crescentic and sloping steeply downwards and inwards to the surface of the diaphragm. As the effusion increases in size the free margin becomes less oblique and less definitely crescentic, and joins the cardiac opacity internally, but even in very large collections the costal aspect forms the highest point of the upper margin. A pleural effusion completely obscures that portion of the diaphragm upon which it rests ; in large right-sided effusions, therefore, the right diaphragm is invisible, but in left-sided lesions the under-surface of the diaphragm can be observed against the air in the gastric cardia, provided the patient can be examined in the upright position. It will then be noted that the diaphragmatic movements are greatly diminished or completely arrested on the affected side.

Displacement of the cardiac opacity towards the sound side occurs in large effusions, and is accompanied by rotation of the heart around a vertical axis. (Plate 49.)

The characteristic appearances of parietal pleural effusions are more readily demonstrated on the fluorescent screen than in a skiagram.

Mediastinal pleural effusions may be anterior or posterior (i.e. in front of or behind the ligamentum latum pulmonis). Small anterior effusions produce an opacity applied to some part of the heart-shadow, and are difficult to demonstrate unless seen in profile. The opacity is then seen to have well-defined margins, and a density greater than that of the adjacent heart. Larger anterior collections produce an opacity parallel with that of the cardiac margin, resembling a double heart outline, and eventually filling out the cardio-phrenic angle. An anterior exudate tends to produce a ribbon-shaped opacity. Posterior effusions are more common and present triangular opacities; the base of the triangle rests upon the diaphragm, the inner side is seen through the heart-shadow, while the outer side, slightly concave, projects beyond the margin of the cardiac opacity.*

Mediastinal pleural effusions are not at all common. They are generally associated with pulmonary tuberculosis.

Interlobar effusions produce dense opacities extending to the lateral parietes from the region of the hilum, and occupying the plane of an interlobar fissure. Both upper and lower borders of the shadow are very clearly defined, and a right-sided effusion can thus be differentiated from middle-lobe consolidation, in which condition the lower margin of the opacity is indefinite.† (Plate 50, Fig. 1.)

Empyema.—It is quite impossible to differentiate radiographically between serous and purulent effusions, and the description given above therefore applies equally to both. Cases of old empyema with persistent sinus are often referred for X-ray examination; the result is frequently inconclusive, as extensive pleural thickening is always present and tends to obscure underlying lung, small retained collections of fluid, and even small pneumothoraces. The extent of the sinus and of any cavity with which it communicates can, however, be demonstrated after injection of lipiodol, which, owing to its thin fluid consistency, is much more valuable for this purpose than the emulsions of bismuth which were formerly used. It is essential that the thin tube or rubber catheter through which the injection is made be passed to the deepest permeable part of the track; attempts to inject the opening of a sinus simply result in the opaque fluid running out over the skin.

Pneumothorax.—In complete pneumothorax the affected

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* Hernheiser, *Fortschritte der Röentgenstrahlen*, 1923.

† Danti, *Amer. Journ. of Roent.*, 1923.

Small parietal pleural effusion.

PLATE 49.

side shows a uniform increased translucency, with complete absence of any lung markings. The collapsed lung is seen as a dense opacity lying by the side of the vertebral column, and usually showing some transmitted pulsation from the cardiac contractions. The heart and mediastina are displaced to the sound side.

The diaphragm on the affected side is depressed and shows restriction of movement. (Plate 50, Fig. 2.)

In partial pneumothorax the lung is seen to be in contact with the parietes over more or less of its extent, and the clear, translucent area is sharply demarcated by the surrounding lung margin and chest-wall. The lung thus partially collapsed presents a general increased density with relative exaggeration of the striate markings ; it is often possible to demonstrate the pulmonary disease responsible for the pneumothorax. (Plate 51, Fig. 1.)

In longstanding cases of pneumothorax in which failure of lung expansion perpetuates what is usually a temporary condition, the chest-wall on the affected side falls in, and the diaphragm is elevated.

An interesting phenomenon can often be observed on screen examination in cases of pneumothorax ; the heart and mediastinum show a slight but definite movement towards the affected side during inspiration, returning towards the sound side on expiration. This is discussed more fully in a later section (p. 134).

In **hydro-** and **pyo-pneumothorax** the appearances of pneumothorax are modified by the presence of the fluid, which in the upright position produces a dense opacity obscuring the diaphragm and maintaining a horizontal upper margin when the patient bends from side to side. (Plate 51, Fig. 2.) Ripples can often be demonstrated by shaking the patient. On inspiration the upper level of the fluid rises in the thorax, to sink again during expiration. This phenomenon has been called the " paradoxical contraction of the diaphragm " ; but observation of left-sided hydro-pneumothorax, in which the lower aspect of the diaphragm is seen against the gas in the cardiac end of the stomach, conclusively demonstrates that the movements of the diaphragm are not reversed but remain synchronous on the two sides ; nor is this structure inverted, as has also been suggested, only a comparatively slight flattening of the normal contour being present. Rist* suggests that this elevation of the fluid level on inspiration is due to the inspiratory excursion of the mediastinum referred to above ; and it would appear that this explanation must be correct.

Radiographically no distinction can be made between hydro- and pyo-pneumothorax.

If it is possible to examine the patient in the supine position only,

* *Proc. Royal Soc. of Med.*, 1925, xviii. 1–7.

the appearances of hydro- and pyo-pneumothorax may be quite mis-leading; the fluid then occupies the posterior part of the pleural cavity, and if at all plentiful will completely obscure the pneumothorax. In these circumstances a skiagram taken in the antero-posterior plane of the thorax, but with the patient lying upon the sound side, affords the best evidence of the nature of the lesion.

Subphrenic abscess produces elevation of the diaphragm on the affected side with restriction or complete absence of movements on respiration, and sometimes obliteration of the costo-phrenic sulcus owing to the approximation of the outer portion of the diaphragm to the lateral chest-wall.* Unfortunately, subphrenic abscess is fre-quently complicated by an effusion into the adjacent basal pleura, due to extension of infection; this pleural effusion is generally small, so that the elevation and immobility of the diaphragm are not necessarily obscured, but as a rule no indication exists as to whether the diaphragmatic condition is due to a primary pleural infection, or to a primary subphrenic collection of pus to which the pleural effusion is secondary; it is frequently impossible, therefore, to make any more definite statement than that the appearances are *consistent* with a subphrenic abscess.

Occasionally a small collection of gas forms below the diaphragm in subphrenic infections. In right-sided lesions this occurrence is of great diagnostic value, as a clear translucent area is seen above the liver; on the left side, such a collection can hardly be differentiated from the common gaseous contents of the splenic flexure and cardiac end of the stomach.

Bronchitis.—Cases of longstanding chronic bronchitis present a well-marked increase in the striate lung markings, and usually a prominent hilar shadow. The increased striation may be sufficient to produce a generalized diminution of translucency over both lungs, except at the apices, into which the markings do not extend. The changes are most marked at the bases. Increased nodular thickenings may be seen at the bifurcation of the striæ, due to enlargement of the lymphoid collections in these situations, but no abnormal opacities are seen in the parenchyma of the lungs. The increased translucency of the lungs in emphysema associated with chronic bronchitis is largely obscured by the increased striation resulting from the latter condition; ıadiography is, in fact, of little value in determining the presence of emphysema in such cases.

In **acute emphysema** occurring in the course of such diseases as whooping-cough and capillary bronchitis in children, the increased translucency is not obscured by any adventitious shadows and presents a very striking appearance. The uniform translucency may almost

* Skinner, *Journ. of Radiol.*, 1923.

Fig. 1.—Interlobar effusion.

Fig. 2.—Complete pneumothorax. Arrows indicate collapsed lung.

PLATE 50.
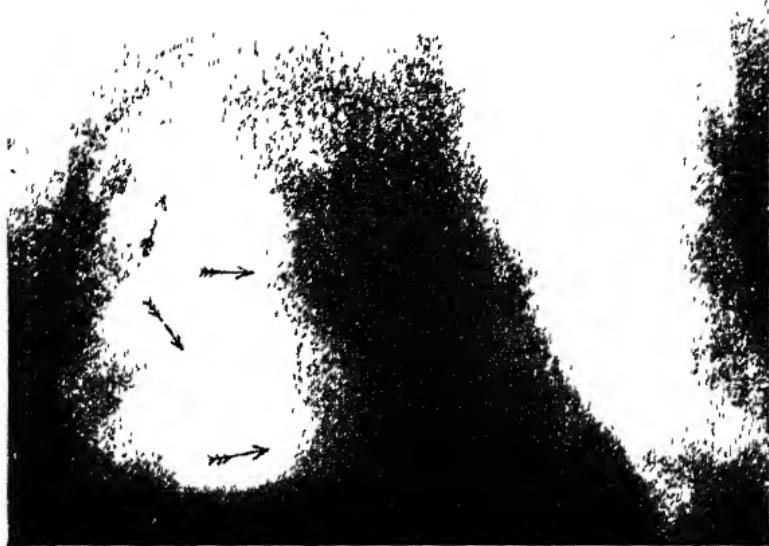
Fig. 1.—Partial pneumothorax. Adhesions between lung and parietes.

Fig. 2.—Hydropneumothorax.

PLATE 51.

simulate pneumothorax, but careful examination of the skiagram will reveal faint lung markings, while the bilateral distribution of the lesion is, of course, in itself conclusive.

Pneumonia.—In broncho-pneumonia a number of very ill-defined opacities are seen ; these may be present over the greater part of both lungs, though more numerous and closely placed at the bases ; or they may be more or less confined to one or more lobes and so closely aggregated as to produce the appearance of a somewhat irregular lobar consolidation. The opacity of the individual areas seen in the former disseminated type is much less dense than the opacity of a true lobar consolidation ; and this is true also, but to a less extent, of the latter confluent type of broncho-pneumonia, although the appearances here may strongly resemble a lobar pneumonia which is in process of resolution.

No radiographic distinction can be made between the opacities due to simple lobular collapse and those produced by inflammatory consolidation in broncho-pneumonia.

As resolution of the disease takes place, the diffuse opacities are seen to become smaller and gradually less numerous. Eventually all these opacities disappear, the parenchyma of the lungs regaining the normal appearances. The presence of scattered or, more commonly, aggregated opacities in the lungs in the late stages of a broncho-pneumonic infection indicates that resolution is incomplete. A certain amount of increased linear striation almost always occurs, however, and persists as a permanent feature in subsequent skiagrams—certainly for several years, and possibly throughout life. Incomplete resolution is accompanied by excessive striation extending into the affected areas.

Lobar pneumonia.—In fully developed lobar consolidation the affected portion of the lung presents, in an antero-posterior view of the thorax, a dense opacity which is uniform except where adjacent to an uninvolved lobe, and this appearance may be noted at the end of twenty-four hours from the onset of the illness. In consolidation of the lower lobe the opacity obscures the upper surface of the diaphragm, but if the lower aspect of this structure can be demonstrated on the left side complete fixation is generally observed. The upper portion of the opacity in a consolidation confined to the lower lobe is somewhat less dense and uniform than elsewhere, and the upper margin is a little hazy owing to the fact that this part is overlapped by the normal upper (and right middle) lobe. Consolidation confined to the right middle lobe presents hazy upper and lower margins in the antero-posterior view of the thorax owing to overlapping of the upper and lower lobes, and an upper-lobe consolidation similarly presents a hazy lower margin in this view. Danti* points out, how-

* *Amer. Journ. of Roent.*, 1923.

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ever, that if a lateral skiagram of the thorax be obtained with the tube centred over the 5th dorsal vertebra, the central radiation corresponds closely to the fissure between the upper and middle lobes. In such a view, therefore, an upper-lobe consolidation presents a uniform density with a clear-cut lower margin ; a middle-lobe consolidation shows a clear-cut upper margin and a hazy lower margin ; while in consolidation of the lower lobe the extreme base is involved and the upper margin of the opacity is hazy.

It will be noted that no view is obtainable of middle- or lower-lobe consolidations in which all the margins are clearly defined, and this fact serves to differentiate an interlobar pleural effusion from a pneumonic lesion.

If seen before consolidation is complete the affected lobe usually shows a fairly uniform opacity extending to the periphery. Sometimes, however, the opacity appears first in the region of the hilum, and spreads rapidly outwards (Danti).

Resolution of lobar pneumonia is shown by the formerly uniform opacity becoming uneven in density, multiple areas of increased translucency separating the intervening opacities. The translucent areas increase in size, coalesce, and the lung parenchyma should appear normal in from three to ten days. Increased striation of the lobe becomes evident, however, as progressive resolution enables lung structure to be demonstrated once more, and this increase persists for an indefinite period—in some cases throughout life.

Incomplete resolution is shown by persistence of irregular, ill-defined opacities which may be scattered over the major part of the lobe, or involve only a comparatively small area.

The presence of a large, well-marked opacity, dense centrally but with ill-defined margins, fourteen days or longer after the crisis, is strongly indicative of lung abscess. If such an abscess discharges into a bronchus a horizontal fluid level may sometimes be demonstrated against the air in the upper part of the cavity, but usually the surrounding consolidation obscures this detail.

A *tuberculous* lobar pneumonia is usually confined to the upper lobe ; though this is an unusual distribution for a pneumococcal lesion, no distinction between the two can be drawn in the acute stages of the disease. A tuberculous consolidation, however, shows no sign of resolution at the end of three weeks, and only resolves with multiple cavity-formation after the lapse of months, if at all.

Fibrosis of the lung.—An increase in the density, width and ramifications of the striate markings of the lung constitutes the condition known as perihilar or peribronchial fibrosis. Such an increase can be observed in the thorax after any pulmonary infection, and is of constant occurrence after such diseases as whooping-cough and

measles, even where coincident bronchitis has possessed no clinical significance.   This perihilar fibrosis persists indefinitely, and in fact may remain permanently without further change.

It follows, therefore, that well-marked striate markings are frequently found in adults who present neither clinical symptoms nor any history of pulmonary disease, the transient affections of childhood having called for no especial comment.

The perihilar fibrosis in such cases presents the following characteristics :—

(1) The increase in prominence of the striate markings is moderate in degree.

(2) The shadows are most dense in the region of the hilum, and diminish progressively through the mid-zone and peripheral zones.

(3) The markings conform to the normal distribution of the bronchial tree, and do not extend into the apical zone or into the extreme periphery of the peripheral zone; nodal points at the bifurcation of striæ are prominent, but there are no opacities in the parenchyma.

(4) The fibrosis involves both lungs more or less symmetrically; it is most marked in the lower lobes, especially in the hilar and mid-zones, but otherwise is distributed fairly uniformly throughout all the lobes.

(5) Apart from this increased prominence of the perihilar striæ, no abnormality is seen in the thorax.

A perihilar fibrosis which conforms to these conditions can for all practical purposes be regarded as possessing no clinical significance.

In other cases the perihilar fibrosis, although still moderate in degree and following the distribution of the bronchial tree, is localized or greatly accentuated in some part of one lung; or localized areas of both lungs may be affected asymmetrically.   The striæ, moreover, extend into areas normally free from lung markings, e.g. the apical zone and extreme periphery of the peripheral zone, indicating an increase in the connective tissue around the terminal divisions of the bronchial tree and pulmonary vessels.   Loss of elasticity in the affected areas, or actual contraction of the adventitious fibrous tissue, may result in slight deviations towards the affected side of the trachea or cardiac opacity, deformity of the diaphragm (notably " tenting " on inspiration), and small angular projections from the cardiac outline; occasionally respiratory excursion of the mediastinum is to be observed, the mediastinal opacity being displaced towards the affected side on inspiration and returning to the normal position on expiration.

Such appearances are indicative of an old localized inflammatory lesion such as lobar pneumonia or tuberculosis.   The absence of

any abnormal opacity except that of the fibrosis can generally be taken as indicating a complete healing of the original inflammatory process, but undue prominence must not be given to radiographic evidence in this respect.

Well-marked perihilar fibrosis of this type may exist without any demonstrable clinical signs ; or loss of elasticity and fibrous contraction may result in clinical features somewhat more prominent than the skiagram would suggest.

True *fibroid lung*, resulting from chronic interstitial pneumonia or fibroid phthisis, shows not only an advanced perihilar fibrosis, but also extensive formation of fibrous tissue which does not conform in distribution to the bronchial tree. This tissue produces large structureless opacities arranged in broad, irregular bands, and may also entirely obliterate all sign of parenchymatous tissue over considerable areas of the lung. In advanced cases the whole organ, or a considerable portion of it, may present an opacity either uniformly dense, or modified by irregular translucent areas indicative of cavitation. Usually the distribution is strikingly asymmetrical on the two sides, and only in the most advanced cases is it uniform over the whole of one lung. The less completely fibrosed tissue generally presents evidence of active inflammatory disease.

It is in this type of pulmonary fibrosis that the mechanical effects of fibrous tissue contraction are most constantly observed. Hence it is usual to demonstrate deviation of the trachea and cardiac opacity, deformity and sometimes displacement and fixation of the diaphragm, angular deformity of the cardiac outline, and respiratory excursion of the mediastinum, all of which have been noted as liable to occur to some extent in the lesser forms of perihilar fibrosis. In addition, it may be possible to demonstrate the presence of *bronchiectasis*, the dilated bronchi appearing as oval or cylindrical translucent areas with thin walls, usually in the hilar and mid zones of the lower lobe. Bronchiectatic cavities are, however, frequently obscured or rendered indefinite in the skiagram by the opacity of the surrounding tissues ; they may then be demonstrated in a skiagram subsequent to intratracheal injection of lipiodol, a method which is described more fully below.

PULMONARY TUBERCULOSIS

In order to appreciate the abnormal radiographic appearances seen in pulmonary tuberculosis, it is necessary to retain a clear conception of the morbid processes which occur in this disease.

These processes, and the changes produced by them in the skiagram, can be classified as follows :

(1) **Formation of tubercles.**—A single grey tubercle varies in size from naked-eye invisibility to a small pin-head. Single tubercles

frequently coalesce, with or without transformation into a yellow tubercle as the result of partial caseation. Radiographically the characteristic appearance is that of groups of small opacities with ill-defined margins, each opacity being twice to three times the size of a pin-head, and therefore representing the coalescence of several grey tubercles. This implies what is an undoubted fact—that the earliest stage of pulmonary tuberculosis may escape detection in the skiagram.

Each group commonly consists of three to five opacities, placed fairly close together, and often situated at the terminal arborizations of a thickened striate marking the trunk of which can be traced to the hilum.

Healing of the inflammatory nodules by transformation into fibrous tissue results in a slight increase of density and diminution in size of the resulting opacity ; each opacity also becomes very plainly defined, with clear, sharp margins, and this perfect definition forms the most valuable evidence of inactivity.

(2) **Inflammatory changes in the bronchioles and alveoli** result in a broncho-pneumonic consolidation of the lung in relation to the tubercles. The relative preponderance of tubercles and of broncho-pneumonia varies greatly in different types of the disease. In some cases tubercles only are seen ; in others tubercles (probably owing to their small size) are absent from the skiagram, the appearances being practically indistinguishable from those of a simple broncho-pneumonia. More commonly the changes seen represent a condition intermediate between these two extremes. The opacities of broncho-pneumonic consolidation are much larger and much less defined than those produced by tubercles.

In some acute tuberculous affections the lobular lesions are so closely aggregated in one lobe that a lobar consolidation is produced, indistinguishable in its early stages from that caused by a pneumococcal infection. Radiographically the broncho-pneumonic consolidations of tuberculosis and of pneumococcal infections are exactly similar ; rather large opacities of irregular shape fading off into the surrounding normal lung tissue without any well-defined margin form the characteristic appearance.

The usual combination of these areas with the small nodular opacities of the tubercles, and with evidence of caseation and sometimes cavity-formation, renders the tuberculous nature of the disease clear.

In those instances, however, where broncho-pneumonic consolidation predominates to the practical exclusion of typically tuberculous changes, correlation with the clinical aspects of the case is necessary for a true appreciation of the lesion.

(3) **Caseation** may occur in nodular tubercles, and in areas of broncho-pneumonic consolidation. In the former case the nodular opacity becomes larger, denser, and with clearly defined margins; a caseous tubercle may attain the size of a small pea. This relatively large size of a clearly defined nodular opacity serves to distinguish the caseous tubercle from one which has healed by conversion into fibrous tissue.

Caseation of the central portion of a lobular consolidation results in a dense nucleus appearing in the centre of the ill-defined opacity resulting from the lesion. The margins of the caseation are not clearly differentiated from the surrounding collapsed tissues, but the increased central opacity is generally quite distinctive. Caseous areas may remain unchanged for long periods; they may become absorbed, with the formation of a scar in the lung, producing a small clearly-defined opacity, often with radiating striæ; they may become calcified, in which case the homogeneous opacity is replaced by a punctate, granular opacity of greatly increased density; or they may liquefy, and by discharge into a patent bronchiole or bronchus give rise to cavity-formation.

(4) **Cavitation,** as stated above, results from liquefaction of caseous material and subsequent discharge through a patent air-passage. A cavity thus formed in an acute phase of the disease presents a translucent area of irregular, frequently sinuous shape with ragged borders formed by the surrounding consolidated lung tissue. This surrounding consolidation, if extensive, may obscure the translucency of the cavity, and undoubtedly many small cavities of this type are not detected in the skiagram.

In the more chronic forms of phthisis cavities are frequently of large size, with smooth walls and well-defined, fairly regular outline, and are surrounded by a zone of dense fibrous tissue which may attain a width of $\frac{1}{2}$–$\frac{3}{4}$ inches. This fibrous wall presents a uniform or laminated opacity clearly differentiated from the surrounding parenchymatous tissue, but often continuous with thickened peribronchial striæ or adjacent collections of connective tissue.

(5) **Proliferation of connective tissue** occurs in all cases of pulmonary tuberculosis except those very rapidly fatal, and in the very chronic forms of the disease is the predominant feature of the skiagram. This proliferation most commonly affects the walls of the bronchial tree, of the pulmonary vessels, and of the deep lymphatics which accompany these structures, and results in a localized, or unilateral, or asymmetrically bilateral perihilar fibrosis with well-marked nodal points as described above. Small fibrous scars are also seen marking the situation of healed caseous areas.

In very chronic phthisis the proliferation not only affects the

perihilar ramifications, but results in the formation of large collections and bands of fibrous tissue compressing and replacing the parenchyma, constituting the walls of cavities, and permeating every part of the pulmonary interstitial structure. Fibrous-tissue proliferation, in whatever degree it occurs, persists as a more or less permanent modification of lung structure in the skiagram. The significance attaching to this modification is discussed more fully above. It may be repeated here, however, that fibrous-tissue proliferation is common to all chronic inflammatory lesions of the lungs, and results also to a slight degree from many transient and insignificant pulmonary infections.

(6) **Enlargement of the bronchial and mediastinal glands.**—Some prominence of the hilar shadow, produced partly by enlargement of the bronchial glands and partly by perihilar fibrosis, is commonly seen in phthisis. No significance can be attached to this appearance unless the hilar shadow definitely extends beyond the limit of the inner, or hilar, zone of the lung. Calcification of one or more bronchial glands, producing dense, granular or uniform, clearly circumscribed opacities, is of very common occurrence, and is observed in a large proportion of skiagrams. Such calcification is indicative of healed inflammatory disease of the affected glands, not necessarily tuberculous in nature.

Crow* states that enlargement of the posterior mediastinal glands (seen in an oblique view of the thorax) nearly always occurs in pulmonary tuberculosis.

(7) **Pleurisy.**—Pleural effusion is a frequent incident in the course of tuberculous lesions. It is most commonly basal, but may be localized by previous pleural adhesions to any part of the peripheral pleura. Interlobar effusions are not usually tuberculous, but mediastinal collections generally represent the unabsorbed residuum of a large tuberculous effusion.

Absorption of pleuritic fluid allows the lymph-covered surfaces to come into contact, with resultant permanently thickened and adherent pleura.

The characteristic appearances of pleural effusion and thickening have already been described (p. 109).

In longstanding chronic pulmonary tuberculosis another type of pleural affection is often noted. The indurated lung constantly resists expansion, and this tends to produce separation of the visceral and parietal pleural surfaces. Œdema of the pleura is the result, producing a diffuse, cloudy, uniform loss of translucency over the affected area in the skiagram. The opposing œdematous pleural surfaces eventually become organized into a single dense layer of fibrous tissue.†

* *Amer. Journ. of Roent.*, 1923.
† Powell and Hartley, " Diseases of the Lungs."

A dense, structureless or faintly laminated opacity is then seen in the skiagram between the lung tissue and the chest-wall. This condition may occur over a wide expanse of the viscus, but is most often noted at the apex, the whole or a large part of the apical zone being replaced in the skiagram by this dense cap of thickened fibrotic pleura.

(8) **Mechanical effects on adjacent structures** result from the loss of elasticity of the indurated lung, and subsequent tendency to contraction of fibrous-tissue proliferation. The œdematous pleura noted above forms one of the manifestations of this condition ; others are collapse and diminished mobility of the chest-wall, upward displacement, deformity and restricted movements of the diaphragm, and displacement of the mediastinal contents, especially the trachea, towards the affected side. Respiratory excursions of the mediastinum may also be observed on fluoroscopy, the mediastinal shadow moving towards the affected side on inspiration, and returning to its former position on expiration.

Types of Pulmonary Tuberculosis

It will be apparent from the above description that practically all the changes produced in the lungs and surrounding tissues by pulmonary tuberculosis can be demonstrated in favourable circumstances by radiographic examination.

It remains to classify the appearances in terms of clinical types of disease.

It is not suggested that this attempt at correlation of clinical and radiological features will always succeed ; but the lessons of experience gained in the endeavour should result in a progressively diminishing percentage of error.

Pulmonary tuberculosis can be classified as belonging to the following types :—

ACUTE PULMONARY TUBERCULOSIS
- (a) *Acute tuberculous lobar pneumonia.*
- (b) *Disseminated forms :*
  - (i) Acute broncho-pneumonic tuberculosis.
  - (ii) Acute miliary tuberculosis.

CHRONIC PULMONARY TUBERCULOSIS
- (a) *Ordinary chronic phthisis.*
  - (i) Peripheral.
  - (ii) Perihilar.
- (b) *Fibroid phthisis.*

Acute tuberculous lobar pneumonia. — This is a comparatively rare form of the disease. The consolidation is possibly of confluent broncho-pneumonic type, but the lesion is clinically and radiographically indistinguishable in its early stages from a simple lobar pneumonia. An antero-posterior skiagram shows a dense

opacity occupying the position of the affected lobe, with a hazy margin when the shadow of this lobe is superimposed upon that of healthy lung tissue. Occasionally the opacity does not extend to all the margins of the affected lobe, and in some cases a few scattered areas of consolidation may be demonstrated beyond the lobar margins.

The disease generally attacks the upper lobe, and this distribution is in itself suggestive of a tuberculous lesion, though by no means pathognomonic.

Tuberculous lobar consolidation resolves very slowly, and resolution is apparently never complete. Three or four weeks after the onset of the illness the opacity shows some unevenness in density, and about the same time it may be possible to demonstrate the formation of multiple cavities. The subsequent progress is very slow, and is marked by extensive cavitation, and, later, fibrosis. At the end of four or five months the lung still presents evidence of patches of consolidation, many cavities, and much fibrous-tissue proliferation, and this condition rarely shows any appreciable amelioration at subsequent examination. Evidence of tuberculosis in the other lobes of the affected lung, and often in the originally sound lung, will generally be forthcoming in these later stages of the disease, the tuberculous manifestations here consisting of groups of small nodular opacities due to tubercles, and scattered ill-defined opacities of much larger size indicative of broncho-pneumonic consolidation.

The tuberculous nature of the infection can only be recognized with certainty on the appearance of the multiple cavitation. Confluent broncho-pneumonia, producing the appearances of an incomplete lobar consolidation, may occur in the course of chronic phthisis, and is not necessarily followed by the extensive cavitation characteristic of the acute primary lesion. Saute* suggests that exacerbations in the course of chronic phthisis are not infrequently due to such confluent broncho-pneumonias.

Acute disseminated broncho-pneumonic tuberculosis.—The disease attacks both lungs and produces multiple scattered .areas of broncho-pneumonic consolidation. No nodular opacities due to tubercles are seen, the disease being at first indistinguishable from an extensive simple broncho-pneumonia. The consolidated areas rapidly break down, however, with the formation of cavities, this process being first observed at the apices,† and the nature of the lesion is then apparent. The disease progresses to a rapidly fatal termination without any evidence of resolution or of repair (e.g. fibrosis). (Plate 52, Fig. 1.)

* *Amer. Journ. of Roent.*, 1924.
† Powell and Hartley, " Diseases of the Lungs."

Acute miliary tuberculosis is characterized radiographically by the presence of closely aggregated, discrete, nodular opacities scattered over all parts of both lungs. These opacities represent the miliary tubercles. Areas of broncho-pneumonic consolidation are absent, or few and inconspicuous. Some of the opacities are occasionally of rather large size and well-defined outline, an indication of commencing caseation, but the disease often reaches its fatal termination without any such evidence of softening. Cavity-formation does not occur.

In some cases of acute miliary tuberculosis in adults the skiagram shows signs of localized chronic phthisis, forming a focus from which the diffuse lesion has possibly been disseminated.

Ordinary chronic phthisis.—Into this class fall the majority of cases of pulmonary tuberculosis. The disease may start in the apices of the upper, middle, or rarely the lower lobe, the upper lobe being rather the more common site of origin ; or the lesions may first be seen in the region of the hilum, and gradually extend outwards and upwards into the middle and upper lobes and, to a less marked degree, downwards into the lower lobe. The peripheral type is much the more common in adults, while in children chronic phthisis usually belongs to the perihilar category.

The earliest radiographic evidence of *peripheral phthisis* consists of one or more groups of the small, ill-defined nodular opacities characteristic of tubercles, most commonly in the apical zone. A thickened striate marking with accentuated nodal points will nearly always be noted extending from the hilum to the region of these opacities. As the disease progresses the nodular opacities become more numerous and spread downwards. Small areas of broncho-pneumonic consolidation are observed, and these may break down with formation of cavities, or may be replaced in more favourable circumstances by localized fibrosis indicating scarring of the lung ; calcification also occurs in these areas not infrequently. Caseation takes place in the tubercles, as shown by their increased size and better-defined margins, and this may be followed by calcification or by rupture into an adjacent bronchiole, with consequent cavity-formation. Instead of breaking down, the tubercles may be converted into fibrous nodules, the opacities then being small and clearly defined.

Perihilar fibrosis is always a prominent feature in the skiagrams of these cases, and pleural thickening or fibrosis is frequently seen. Although the more obvious foci of disease may first appear in almost any part of the lung, Bissell* states that abnormal markings can be observed in the apical zone in every case.

* *Amer. Journ. of Roent.*, 1923.

Fig. 1.—Acute pulmonary tuberculosis of both lungs, more advanced in right.

Fig. 2.—Chronic pulmonary tuberculosis. Extensive disease in upper lobes.

PLATE 52.
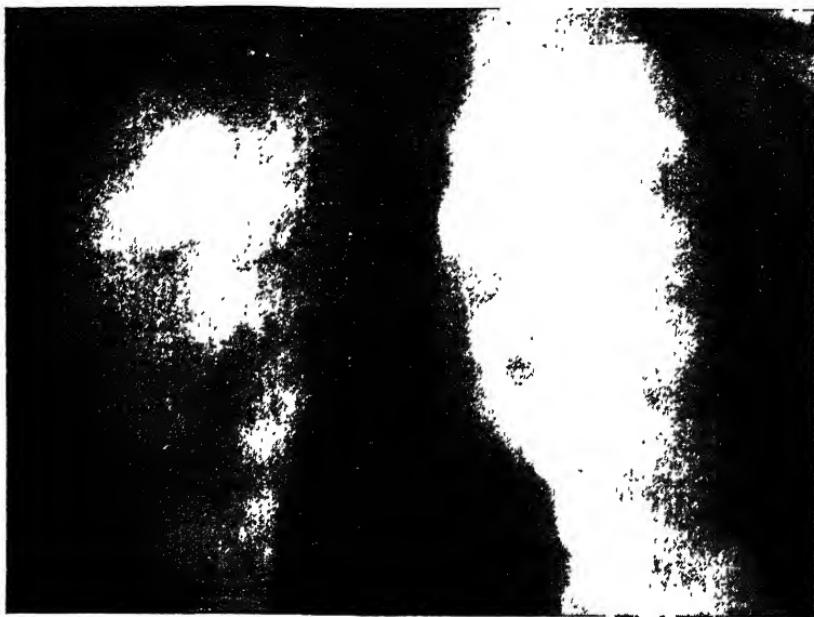
Fig. 1.– Chronic pulmonary tuberculosis with extensive fibrosis of right lung.

Fig. 2.—Chronic pulmonary tuberculosis of right upper lobe. Cavity below clavicle marked with arrows. Pleural thickening at apex.

PLATE 53.

The disease often appears in the apex of the middle lobe, and in the other lung before the whole of the upper lobe is involved.

In advanced cases of long standing practically all parts of both lungs may show evidence of the disease. The older lesions frequently appear healed (calcified or converted into fibrous scars), activity being most apparent in the zones more recently invaded. After very extensive lesions have occurred, diffuse fibrosis may convert the condition into one of fibroid phthisis, indistinguishable radiographically from a lesion primarily of this type.

The frequent observation of scars and areas of calcification in the apices of individuals apparently healthy proves beyond doubt that in many cases the lesions of chronic phthisis remain localized and heal. In those cases which present physical signs and symptoms of active tuberculosis, on the other hand, the skiagram usually reveals a more extensive distribution of disease than is suspected on clinical examination. (Plate 52, Fig. 1, Plates 53, 56, Plate 54, Fig. 1.)

In *perihilar tuberculosis* nodular opacities and areas of broncho-pneumonic consolidation first appear in the region of the hilum, and gradually spread outwards and upwards towards the periphery of the upper and middle lobes. Perihilar fibrosis is a constant and prominent feature, the thickened striæ extending from the hilum to the multiple areas of disease, and often preceding the demonstrable extension of disease towards the periphery ; the nodes at the bifurcation of the striæ are generally very well marked, but these do not constitute definite evidence of active tuberculosis in the absence of typical opacities of tubercles or broncho-pneumonic consolidation. Cavitation is rare in this form of phthisis, as is involvement of the pleura. The disease at the worst is very slowly progressive, and probably often becomes arrested and healed without being detected. (Plate 54, Fig. 2.) Perihilar tuberculosis as a primary active lesion is not common except in childhood, and great caution should be exercised in expressing an adverse opinion on observing localized fibrosis and indefinite opacities, confined to the region of the adult hilum, even if the adjacent mid-zone is involved. In the majority of instances these appearances represent healed disease. When any reasonable doubt exists as to the interpretation of such appearances, re-examination after the lapse of six weeks or two months should be recommended. If at the second examination no extension of abnormality can be demonstrated, it is fairly safe to assume the absence of active tuberculous disease.

Fibroid phthisis.—This disease in its fully developed form is necessarily unilateral, but in a less advanced phase may affect some

parts of both lungs ; possibly these latter cases are examples of fibroid transformation of ordinary chronic phthisis.   In a typical case of fully developed fibroid phthisis the affected side of the chest is contracted and the diaphragm elevated, deformed, and more or less immobile. The mediastinal contents are displaced towards the diseased side. The lung structure is often greatly obscured by densely thickened pleura, but it is generally possible to make out the presence of strands and collections of fibrous tissue, producing uniform or striated opacities, in such amount as to obliterate or conceal normal lung parenchyma over wide areas.   Where lung tissue can be distinguished, areas of consolidation are often observed.   Cavities with thick fibrous walls are generally present, and the thin-walled cylindrical or rounded translucencies of dilated bronchi are constantly apparent in the mid- and hilar zones, especially of the lower lobe.

The presence of multiple cavities, and the formation of extensive fibrous tissue independent of peribronchial fibrous ramifications, serve to distinguish fibroid phthisis from fibroid lung due to other causes. (Plate 55.)

Annular shadows.—In many cases of chronic pulmonary tuberculosis the figures known as annular shadows are observed.   These consist of rounded or roughly oval linear opacities, smooth and regular in contour, forming the thin-walled boundary of a central translucent area, which shows normal lung structure, or lung structure modified by involvement in the existing tuberculous process.   The annular shadows appear, in fact, to exist radiographically as isolated entities, having no obvious relation to any changes which may be seen beyond their periphery or enclosed within their circumference.   They are most common in the upper lobe towards the apex, but may be seen in any part of the lung ; they are sometimes roughly symmetrical in the two lungs.   They vary from the size of a penny to that of an orange. (Plate 56, Figs. 1, 2.)

Since these shadows were first observed, discussion has raged as to their correct interpretation.   Two opinions are at present in vogue—(1) that all annular shadows represent cavities in the lung ; (2) that the shadows are caused by linear pleural thickenings around small localized pneumothoraces.

Against the theory of cavitation must be set the following considerations :

(*a*) The annular shadow is often very large, and frequently situated near the apex, i.e. in a part readily accessible to clinical examination ; yet the physical signs of cavitation are usually absent.

(*b*) Neither the general condition of the patient nor the extent of the tuberculous lesions may be consistent with large cavitation.

(*c*) Small cavities are sinuous or irregular in shape, often with

Fig. 1.—Multiple calcified lesions in healed pulmonary tuberculosis.

Fig. 2.—Perihilar pulmonary tuberculosis of both upper lobes.

PLATE 54.
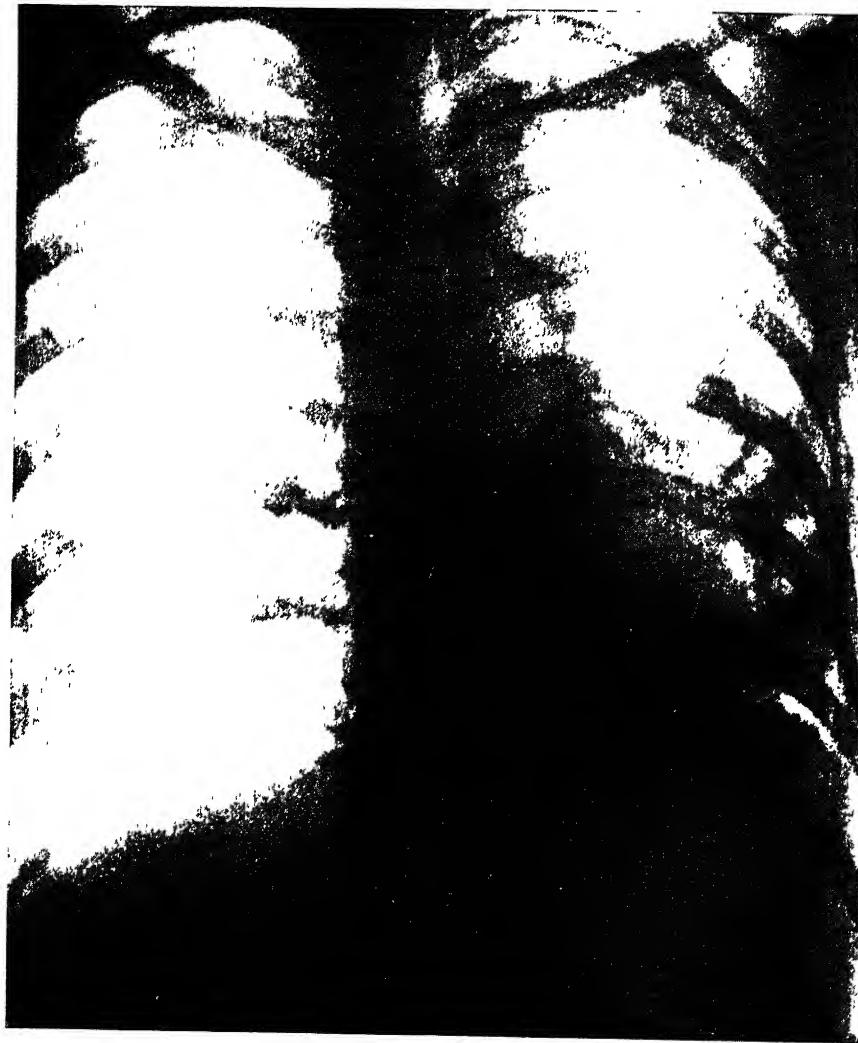
Fibroid phthisis of left lung. Extensive active tuberculosis of right lung.

PLATE 55.

ragged walls ; large cavities have thick fibrous walls : in either case there is usually evidence of extensive disease in the immediately adjacent lung tissue. Annular shadows are always quite regular in outline, and the linear margin is never very thick.

(d) The area enclosed by the annular shadow shows little if any increased translucency, nor does it vary in translucency on different occasions to suggest transient fluid retention. The shadow may undergo rapid variations in size.

(e) Production of artificial pneumothorax has sometimes caused disappearance of an annular shadow, with failure to reappear on subsequent expansion of the lung.*

As regards the second theory, it must be admitted that no clinical or pathological evidence exists as to the frequent occurrence of localized pneumothoraces in phthisis, while, on the other hand, annular shadows are exceedingly common ; moreover, cases are on record of supposed annular shadows which have proved to be " silent " cavities.

It appears certain that in many cases annular shadows do not represent cavities, though their true explanation remains in doubt. At the same time, the possibilities of error noted above should emphasize the need for extreme caution and for correlation with the clinical evidence before forming a favourable opinion as to the significance of such shadows.

Pulmonary syphilis.—Pulmonary manifestations of syphilis are not at all common. The diffuse consolidation ("white hepatization ") of congenital disease is probably the most frequent syphilitic affection of the lungs, but this does not concern the radiologist owing to the infant's brief survival.

Diffuse consolidation of somewhat similar type but much more limited in extent very occasionally occurs in tertiary syphilis. The lower lobe is usually involved, and shows in the skiagram a mass of ill-defined confluent opacities with irregular margins, the distribution being chiefly along the course of the larger bronchi and adjacent to the cardiac border. †

The type of tertiary lesion usually encountered takes the form of multiple gummata. These may occur in any part of the lung, and produce opacities varying in size from a sixpence to a penny. The opacities are dense, are not confluent, and their margins are ill defined and irregularly rounded, often connected with fibrous strands extending into the adjacent lung tissue. The centres of the opacities may be less dense than the periphery, and central liquefaction may lead to cavity-formation. Usually, however, the lesions become

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* Melville, *Brit. Journ. of Radiol.*, 1926.
† Watkins, *Amer. Journ. of Roent.*, 1921.

converted into fibrous tissue, showing a dense fibrous scar with radiating strands of a similar structure.

Cavities, where they occur in gummatous disease, are always small. The large size and irregular distribution of the opacities, the marked tendency to complete fibrosis, and the absence or small size of cavities are features which distinguish the disease from the broncho-pneumonic consolidation of tuberculosis.

Gummatous disease of the lungs generally has its onset from six to twelve years after the primary infection, and is usually accompanied by other specific manifestations. It must be remembered, however, that phthisis occurs with some frequency in those debilitated by the cachexia of syphilis, so that the nature of the pulmonary disease must be decided on its own merits.

Dense perihilar fibrosis of the lungs and fibrous thickening of the pleura are sometimes observed in cases of old syphilis, without evidence of gummatous formation. These appearances are probably in some instances due to healed gummatous lesions, but there appears to be a tendency towards perihilar fibrosis in late tertiary syphilis without any other demonstrable pulmonary abnormality. It is probably due to thickening of the arterial walls.

Syphilitic ulceration of a bronchus occasionally occurs, and may lead to obstruction by cicatricial contraction. The skiagram will then show collapse of the obstructed lung tissue and the formation of bronchiectases; there is no feature distinguishing this from other forms of obstruction.

Silicosis is not of very frequent occurrence in this country, but presents a very grave problem in certain areas, especially of South Africa and the United States, where large numbers of workers are exposed to the danger of contracting the disease.

The fine inhaled dust is deposited in the smallest bronchioles and the alveoli, and is for some time carried by the lymphatics to the bronchial glands. This results in increased size and density of these glands, the latter change being due to accumulation of the minute silicic particles. After months or years of continued inhalation of the dust the bronchial glands and immediately adjacent lymphatic trunks become blocked, and the linear striæ show increased width and density owing to accumulation of particles and fibrosis. The minute collections of lymphoid tissue situated at the bifurcations of the bronchi also become enlarged, forming well-marked nodes at the divisions of the linear lung-markings.

According to Dunham and Jarvis* these nodes can be divided into three sets. The proximal set appear in the hilar zone, and form the apices of triangles of which the bases are formed by nodes in the mid-

* *Amer. Journ. of Roent.,* 1921
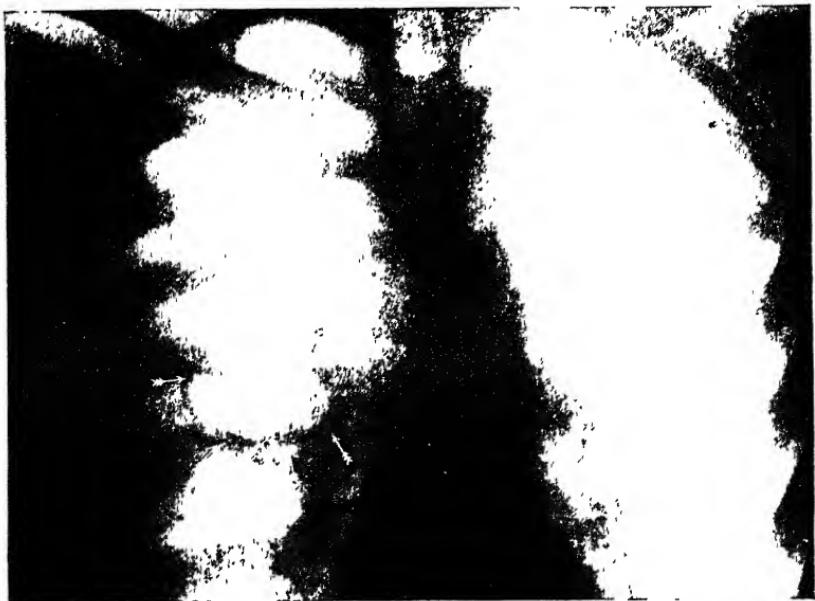
Fig. 1.—Large annular shadow in right lung.   Moderate perihilar fibrosis radiating from annular shadow.
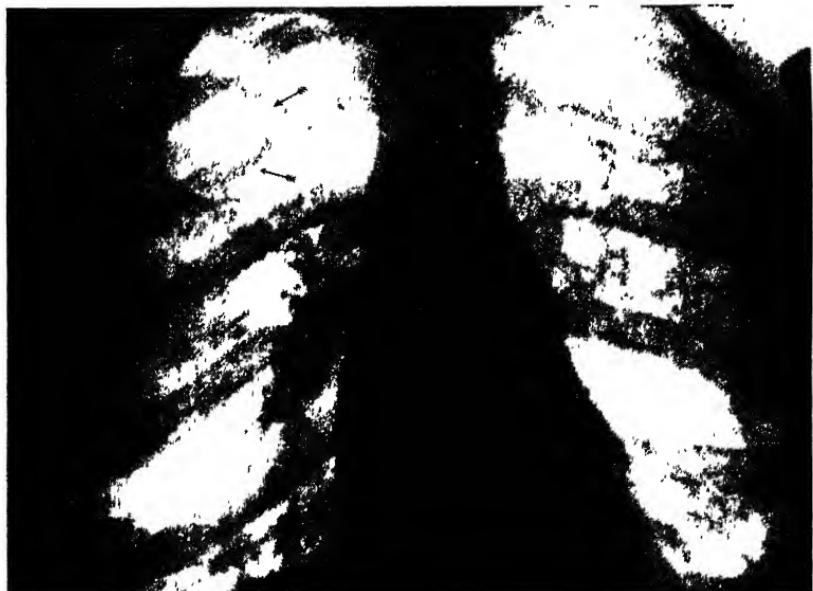
Fig. 2.—Chronic pulmonary tuberculosis of both lungs.   Two annular shadows marked with arrows.

PLATE 56.
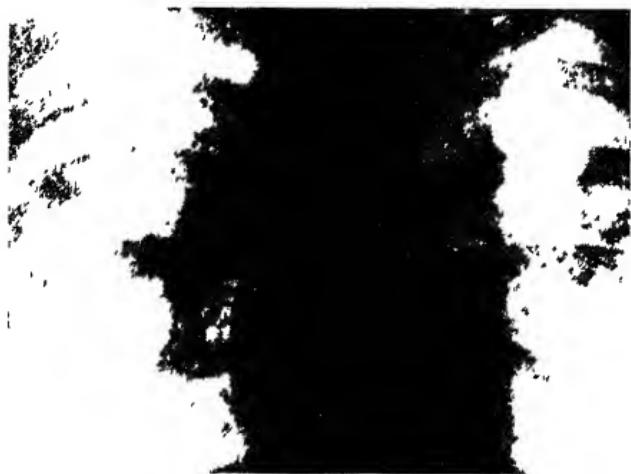
Fig. 1.- Silicosis.

Fig. 2.—Enlarged mediastinal glands in lymphadenoma (Hodgkin's disease).
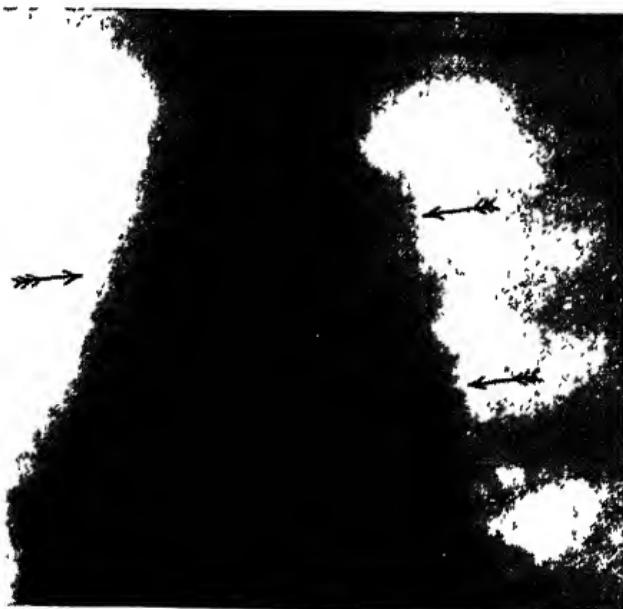
Fig. 3.—Mediastinal neoplasm.

PLATE 57.

zone ; each of these medial, mid-zone nodes again forms the apex of a triangle of which the base is represented by nodal points in the inner portion of the peripheral zone

The proximal nodes appear first, and are followed successively by the medial and peripheral nodes

According to this conception the lung markings become defined as a series of triangular figures of which the sides are formed by the bifurcations of the linear markings.

These figures are known as " Dunham's triangles," and their appearance represents the accumulation of dust in the lymphatics owing to progressive obstruction of the bronchial g'ands and bifurcation nodes of lymphoid tissue. This observer describes the later formation of fan-shaped opacities (" Dunham's fans " or " cones ") in the peripheral zone, due to obstructed drainage from the alveoli themselves.

Each fan does not present a uniform density, but one consisting of numerous small, closely aggregated opacities. (It must be noted that the peripheral zone extends around the whole costal aspect of the lung, so that the antero-posterior skiagram will show these discrete opacities scattered over the whole pulmonic field, and not confined to the lateral aspect of the thorax as might be imagined from some diaphragmatic representations of cone-formation.)

Ultimately a faint homogeneous opacity may appear over the lung, indicative of alveolar drainage through the subpleural lymphatic system.

Other observers who have recorded a large number of examinations on those liable to silicosis do not accept this rather elaborate analysis of the radiographic appearances, but are content with stating that multiple small discrete opacities appear over all parts of the pulmonic fields as seen in the skiagram, after a preliminary stage denoted by increased size and density of the hilum shadow and of the linear markings. (Plate 57, Fig. 1.)

As the disease progresses, groups of the discrete opacities tend to coalesce so that the opacities increase in size but diminish in number.* Eventually, however, the lungs are closely studded with these opacities.

The subjects of silicosis are not infrequently attacked by pulmonary tuberculosis, the earlier radiographic manifestations of which are apt to be obscured by the existing perihilar fibrosis and multiple opacities.

Enlargements of the mediastinal glands, other than those due to neoplasm, occur as the result of adenitis (usually tuberculous), in Hodgkin's disease, and sometimes in lymphatic leukæmia.

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* Steuart, *Arch. of Radiol.*, 1923.

Mediastinal adenitis is not often very obvious in *phthisis*, although Crow* considers that an oblique view of the thorax will demonstrate enlargement of the posterior mediastinal glands in all cases of this disease. The superior mediastinal glands are sometimes subject to tuberculous infection in children, and result in increased width of the superior mediastinal opacity. It is to be noted that this is by far the most common cause for such an abnormality in early life.

There can be no doubt that prominence of the hilar shadow is often due to tuberculous adenitis of the bronchial glands ; but this shadow is subject to such wide variations in apparently healthy subjects that a diagnosis of definite pathological enlargement of the bronchial glands as a result of inflammatory disease can rarely be made from the radiographic appearances.

The mediastinal glands are nearly always enlarged in *Hodgkin's disease* (lymphadenoma) ; extensive intrathoracic involvement not infrequently precedes any noticeable affection of the superficial glands, and persists after treatment has reduced all palpable glandular swellings to vanishing point or insignificance. Systematic radiography of the thorax should, in fact, be constituted a routine practice in checking the progress of this disease.

The superior mediastinal glands are those most often involved. In the earlier stages a smooth rounded opacity is seen projecting from one side of the superior mediastinal shadow. In the skiagram the margins of this opacity can be distinguished in their entirety, owing to its increased density in relation to the mediastinum, and the fact that no adhesions to adjacent structures are formed. At a later stage of the disease masses will be seen projecting from either side of the superior mediastinum. The outline becomes irregular owing to the mass being made up of many glands, but the margins of the opacity remain perfectly defined, and no changes whatever are seen in the adjacent lung. Similar clearly defined opacities are seen in the hilum, as a result of involvement of the bronchial glands, and here again are unaccompanied by any evidence of pulmonary involvement. The posterior mediastinal gland may also be involved. The diagnosis from neoplasm rests upon the smooth, clearly defined, generally convex, contours of the opacities, and the complete absence of invasion of the adjacent tissues ; if seen at a very early stage, however, it may be impossible to exclude neoplasm with any degree of confidence on the radiographic appearances alone. (Plate 571, Fig. 2.)

Enlargement of the mediastinal glands also occurs in the more chronic form of *lymphatic leukœmia*. The appearances produced in the skiagram are similar to those of Hodgkin's disease, but intra-

thoracic glandular involvement is slight compared with the enlargement of the superficial and abdominal glands.

Persistent thymus.—Persistence of the thymus gland results in an opacity somewhat resembling the conventional heart-shape inverted. The opacity is therefore broader below, where it blends with the cardiac shadow, and presents symmetrical convex, bulging, lateral margins which converge in the upper part of the thorax. The great vessels are obscured. The opacity increases in size when the child cries.

The diagnosis from tuberculous enlargement of the superior mediastinal glands rests upon the smooth, symmetrical convex borders of the shadow, and the increased size on crying. The distinction between the two conditions is, however, very difficult, and the diagnosis of persistent thymus should not be indulged in lightly; in the vast majority of cases increased width of the mediastinal shadow in children is due to tuberculous adenitis.

OTHER LESIONS OF THE RESPIRATORY TRACT

INTRATHORACIC NEOPLASMS

TUMOURS may arise either in the mediastina or in the lungs. The former do not, of course, properly belong to the respiratory tract, apart from secondary involvement, but are most conveniently considered in conjunction with the primary pulmonary growths.

Mediastinal tumours may be either benign or malignant. Among benign tumours reported are fibromas, dermoids, lipomas, chondromas and hydatid cysts. *Dermoid cysts* produce dense round opacities usually projecting from the right side of the mediastinum. The opacity is uniform, unless modified by bone or dental formations within the cyst, and can be clearly differentiated throughout its whole extent from adjacent and superimposed shadows.

Echinococcus cysts also present sharply-defined, round, uniform opacities, usually projecting from the margin of the heart-shadow. The clearly-defined margins and round shape of these cysts and the absence of any involvement of adjacent structures usually suffice to establish a diagnosis of benign neoplasm.

Primary sarcoma arising in an intrathoracic lobe of the thyroid, or in the remnants of the thymus, may present a very clearly defined large opacity, but this is not round in shape ; nor are the glandular enlargements of lymphadenoma. The outline of a sarcoma arising from the mediastinal glands is generally irregular.

The other benign tumours which have been noted as arising in the mediastinum are so rare that no adequate description can be given of their X-ray appearances. Presumably, however, they would present a well defined margin, clear differentiation from surrounding shadows, and absence of involvement of adjacent structures. Punctate or granular opacities in such a mediastinal mass would suggest calcification in a chondromatous tumour.

Malignant tumours of the mediastinum are usually small round-celled sarcomas. The growth usually arises from the superior mediastinal glands and produces a dense uniform opacity generally extending to both sides of the mediastinal shadow and often roughly symmetrical in its earlier stages. The margins of the opacity may

be quite smooth, or may present a very ragged, ill-defined appearance ; the outline is usually irregular in shape. (Plate 57, Fig. 3.) The opacity tends to spread downwards along the pericardium, with which it blends, to the hilum. Thence the growth may invade the lung along the course of the larger bronchi, producing a dense uniform mass clearly defined from the adjacent lung tissue. When extensive invasion of the lung has occurred it may be impossible to distinguish the lesion from a primary lung tumour with secondary mediastinal deposits. In less advanced invasion the relative sizes of the pulmonary and mediastinal opacities serve to indicate the probable site of origin. It is stated elsewhere that the parenchyma surrounding the pulmonary invasion of growth usually shows no abnormality. This is not always the case, however, as invasion of the hilum may result in obstruction of a main bronchus, with subsequent collapse of that portion of the lung to which its subdivisions are distributed.

The growth sometimes invades both lungs, but to an unequal extent.

Sarcoma of the mediastinum does not always involve the lungs by direct extension ; in fact, some observers consider that this mode of growth is rather infrequent. Secondary metastatic deposits in the lungs are certainly quite common, either in conjunction with direct invasion or as the sole representatives of the tumour in the pulmonary tissues. The appearances of secondary deposits are described below.

If a superior mediastinal sarcoma is seen before extension of the growth into the hilum, or the formation of pulmonary metastases, the appearances may closely simulate those of aortic aneurysm, and differentiation of the two lesions may be a matter of extreme difficulty. A correct diagnosis can usually be arrived at by the recognition of one or more of the following features :—

(1) Aneurysm is often a unilateral extension of the mediastinal shadow ; the opacity of neoplasm generally appears beyond both lateral margins of the mediastinum.

(2) The shadow of the normal aorta may be distinguished in cases of neoplasm. If this is possible the presence of aneurysm is definitely excluded.

(3) The margins of the shadow of aneurysm are generally smooth and rounded. In neoplasm the margins may be smooth and very well defined, or ragged and indefinite ; in either case they tend to irregularity of shape.

(4) The shadow of an aneurysm should show expansile pulsation ; that of neoplasm shows only transmitted pulsation in one plane. It must be admitted, however, that expansile pulsation in an aneurysm is often exceedingly difficult to determine. (*See* Plate 63, Fig. 2.)

Mediastinal sarcoma does not invariably arise in the superior mediastinal glands, but may originate from the posterior mediastinal glands, loose connective tissue, or from an intrathoracic lobe of the thyroid or a persistent thymus. The appearances in the skiagram are not appreciably modified from those described above allowing, of course, for the altered site of the opacity. Thyroid and thymic growths, however, tend to retain a smooth, well-defined outline, even when of large size.

Secondary malignant deposits in the mediastina can only be distinguished from primary growth by recognition of the remote primary lesion.

Pulmonary tumours. — The same varieties of benign tumours have been noted in the lungs as in the mediastina, viz. lipomas, chondromas, fibromas, dermoid and echinococcus cysts. All are extremely rare with the exception of the echinococcus cyst. This growth produces a well-rounded, smooth-walled, perfectly defined and uniform opacity, usually situated in the lower lobe and generally of large size when first observed. No surrounding lung changes are seen.

The diagnosis from malignant neoplasm and inflammatory lesions is generally easy, the large size, round shape and sharp margins of the opacity, and the absence of other abnormality in the thorax, being very distinctive. Other benign tumours would presumably produce similar appearances. (Plate 58, Fig. 1.)

Malignant tumours of the lungs may be primary or secondary. Primary pulmonary growths are now known to be generally carcinomas. No radiographic distinction can, however, be made between carcinoma and sarcoma.

Two main types of primary growth are seen, the pneumonic or lobar, and the hilar.

The *pneumonic* type of tumour is the more common, generally affects the upper lobe, and produces a dense opacity involving the whole of, and sharply limited to, this lobe. The opacity attains this large size while the growth is still quite small, as the shadow represents a chronic pneumonic consolidation induced by the presence of the neoplasm. The opacity is fairly uniform, but may become less dense towards the apex and lateral chest-wall. The diaphragm is elevated and shows diminished mobility, and respiratory excursion of the mediastinum may be observed.*

Pleural effusion is common, and may obscure the primary lesion, especially where this is not situated in the upper lobe.

The appearances of a lobar carcinoma bear a striking resemblance to those of lobar pneumonia, and the history and clinical features of

* Thomas and Farmer, *Amer. Journ. of Roent.*, N.S., 1924, xi. 391–405.
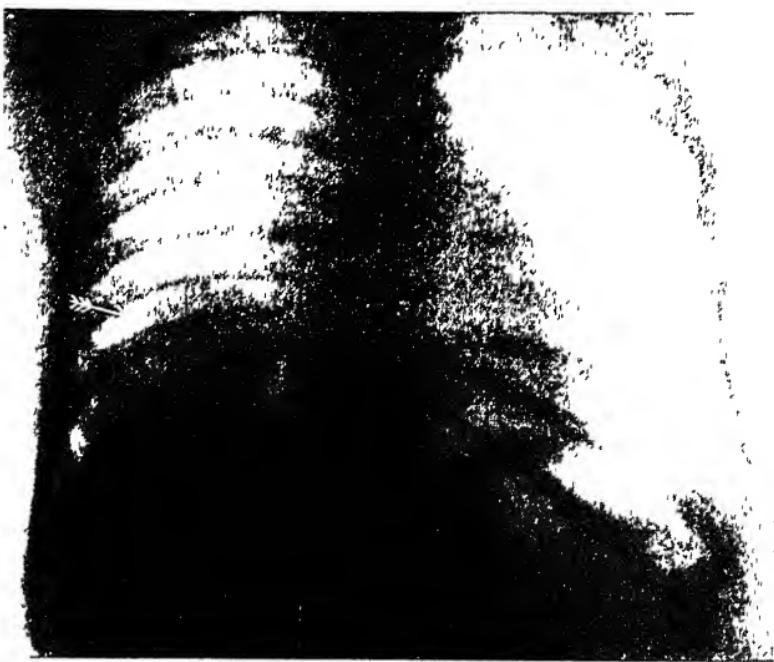
Fig. 1.—Hydatid cyst of right lung.

Fig. 2.—Primary neoplasm of lung, lobar type.

PLATE 58.

Fig. 1.—Primary neoplasm of lung, hilar type.
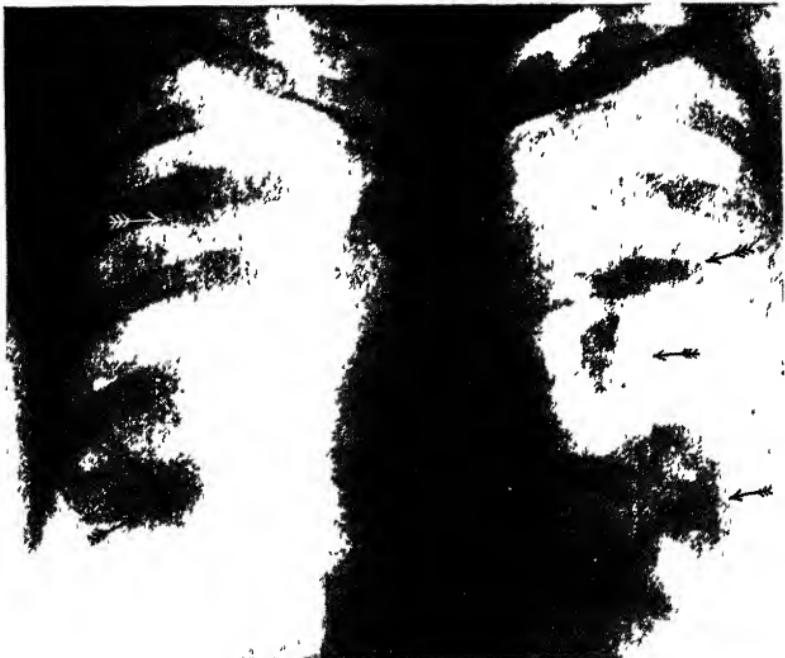
Fig. 2.—Secondary carcinomatous deposits in lungs.

PLATE 59.

the case probably form a much more reliable guide to differentiation than any radiographic distinction. Thomas and Farmer (*ibid*.) point out that the aortic arch is pushed away from the affected side in the earlier stages of neoplasm, while in lobar pneumonia displacement tends to occur towards the disease. In the later stages of neoplasm, however, displacement of the aorta towards the growth is observed, especially if obstruction of the main bronchus, with subsequent complete collapse of the lobe, has occurred. (Plate 58, Fig. 2.)

In the *hilar* type of carcinoma the normal hilar shadow is replaced by a uniform, very dense opacity with a rounded outer border ; this opacity is often very large when first observed, extending well out into the mid-zone of the lung and occupying a considerable proportion of the whole hilar zone. The margins of the opacity may be very clearly defined, or may present an irregular appearance due to many small striæ spreading out into the adjacent lung. Distinct nodular opacities may also be present in the peripheral portion of the lung. As a general rule, however, the lung parenchyma shows little if any abnormality, unless collapse results from obstruction of a main bronchus. In advanced stages of the disease the lung may be almost entirely replaced by growth, and the mediastinum is in these cases displaced towards the sound side.

Hilar carcinoma is distinguished from mediastinal neoplasm invading the lung by the absence of any abnormal mediastinal opacity, or the relatively small size of such an opacity should secondary involvement of the mediastinal glands have taken place.

Pleural effusion tends to occur in this as in the pneumonic form of growth. (Plate 59, Fig. 1.)

Two further types of primary lung carcinoma are described, both very rare (Thomas and Farmer, *ibid*.). A *nodular* type, in which large, well-defined opacities appear in the parenchyma of one lung, and are associated with dense perihilar fibrosis, this fibrosis and the unilateral distribution of the lesions serving to exclude secondary metastases ; and a *cavernous* type, in which the skiagram shows a large solitary cavity, which cannot usually be distinguished from lung abscess or tuberculous cavitation.

Secondary neoplasms of the lung, consisting of either carcinomatous or sarcomatous metastases, are practically always bilateral in distribution when first observed. The opacities produced are usually sharply defined, and unaccompanied by any changes in the surrounding lung structure. Occasionally the opacities present irregular striæ extending from their periphery into the adjacent pulmonary tissues.

Two types of metastatic deposit may be observed, (1) a nodular and (2) a miliary type. .

(1) In the *nodular* type multiple large rounded lesions occur in both lungs, usually more numerous in the lower lobe, and rarely if ever involving the upper portion of the upper lobe. The opacities are of moderate density, and are generally sharply defined, but the margins are sometimes seen to shade off rather rapidly into the surrounding lung tissue, and to present short, ill-defined radiating striæ. (Plate 59, Fig. 2.) The bilateral distribution of the lesions serves to distinguish metastatic neoplasm from the rare nodular form of primary carcinoma of the lung. The comparative absence of changes in the surrounding parenchyma (e.g. fibrosis) is the chief point of distinction between secondary deposits and multiple gummata, but the resemblance between the appearances of these two conditions may be very striking, and clinical confirmation of the diagnosis is essential.

(2) The *miliary* type of metastasis is quite rare ; it is perhaps slightly more common in sarcoma than in carcinoma. Both lungs are seen to be studded with small, discrete, clearly defined opacities, the intervening parenchyma showing no abnormality ; the upper thirds of the lungs usually show comparative freedom from deposits. The appearances of this condition bear a considerable resemblance to those of miliary tuberculosis, but the opacities, though small, are definitely larger than miliary tubercles.

Hypernephroma sometimes results in a deposit in the base of the lung, producing a single massive growth which may occupy a considerable portion of the lower lobe.

Respiratory excursion of the mediastinum consists in a lateral displacement of the mediastinum on inspiration, with return to its former position on expiration. The respiratory excursions are independent of any permanent displacement of the mediastinum which may have resulted from the causative lesion. Rist,* to whose researches on this subject much of our knowledge is due, states that the phenomenon occurs in stenosis of a main bronchus, unilateral pulmonary fibrosis, and closed pneumothorax. The excursion is also sometimes seen in the pneumonic type of pulmonary carcinoma. The deviation of the mediastinum is towards the affected side on inspiration in all cases, and may amount to 1 inch of displacement of the heart-shadow ; usually, however, the movement is $\frac{1}{2}$–$\frac{3}{4}$ inch. The whole of the mediastinum shares in the displacement, but not in equal measure, the movement resembling that of a pendulum suspended at the thoracic inlet, and being therefore greatest in the lower part of the cardiac opacity.

Rist's explanation of these respiratory excursions is as follows :—

* *Proc. Roy. Soc. of Med.*, 1925, xviii. 1–7.

In *stenosis of a main bronchus* the fall of intrathoracic pressure which occurs on inspiration is very rapidly compensated on the sound side by the atmospheric pressure of the inspired air. On the affected side, however, this compensation takes place much more slowly, with resultant temporary inequality of pressure in the two lungs and displacement of the mediastinum towards the affected side. If the breath is held at the end of inspiration this inequality is gradually overcome, and the mediastinal opacity consequently returns to its normal position ; this does not occur in mediastinal excursions due to unilateral fibrosis or pneumothorax. On expiration in bronchial stenosis the inequality of pressure is reversed, the affected lung showing a temporary increased tension of its contained air as compared with the sound lung, and expiratory displacement of the mediastinum away from the obstructed side is observed.

In *unilateral fibrosis* the mediastinal excursion towards the affected side results from loss of elasticity in the diseased lung.

Respiratory excursions of the mediastinum are constantly seen in artificial *pneumothorax,* and are fairly frequent in those cases of closed pneumothorax which result from pulmonary disease. Excursions do not occur in pneumothorax resulting from open wounds of the thoracic parietes, either operative or accidental.

The explanation is that inspiratory expansion of the thorax tends to lower the pressure of the gas forming a closed pneumothorax, while the fall of alveolar pressure on the sound side is slight and transient.

To Rist also belongs the credit of offering the only explanation consistent with the demonstrable facts to account for the phenomenon hitherto known as **Kienbock's paradoxical movement of the diaphragm.** As mentioned in a previous chapter, this phenomenon is observed in cases of hydro-pneumothorax, and consists in a rise of the fluid level during inspiration, and a fall on expiration—i.e. the fluid level moves in the opposite direction to the diaphragm on the sound side during both phases of respiration. The suggestions formerly put forward to account for this reversal were :

(1) That the diaphragmatic movements were reversed on the affected side.

(2) That the pressure of the fluid, and the absence of elastic tension imposed by the normal expanded lung on the diaphragm, combined to invert this structure to a downward convexity, contraction of which diminished the capacity of the affected side of the thorax.

Both these theories can be conclusively disproved by observation of the diaphragm outlined by gas in the cardiac end of the stomach in left-sided hydro-pneumothorax.

The movements of the diaphragm on the affected side are seen to be diminished but normal in direction, and only a slight flattening of the diaphragmatic dome is observed.

Rist suggests that the capacity of the affected side of the thorax is actually diminished on inspiration by the excursion of the mediastinum, this diminution of capacity resulting in the elevation of the fluid level.

Eventration of the diaphragm and diaphragmatic hernia.—Petit's " eventratio diaphragmatica " consists of a permanent congenital elevation of one side of the diaphragm, practically always the left. The affected leaf lies at a high level in the thorax, the upper limit of the dome sometimes extending to the 2nd rib. The movements are inverted or absent, the former phenomenon being due to the transmission of respiratory variations in intra-abdominal pressure, the leaf itself being inert.

The elevated diaphragm forms an unbroken bowline.* Beneath this is an air-space bounded below by a horizontal fluid level which lies in the plane of the cardiac end of the stomach. Lung markings are usually observed through this domed air-space, owing to extension downwards of the lower lobe of the lung behind the elevated diaphragm.

A similar condition results from acquired unilateral phrenic paralysis, resulting either from trauma in the neck or disease in the thorax. Differentiation is often rendered possible by demonstration of primary intrathoracic disease (usually a mediastinal neoplasm) in the acquired type of lesion.

As previously mentioned, a moderate temporary elevation of the left diaphragm may occur from gaseous distension of the stomach or splenic flexure ; in these circumstances the diaphragmatic movements remain normal in direction though often restricted in extent.

Permanent elevation of the diaphragm must be distinguished from diaphragmatic hernia.

In this condition the stomach, usually the splenic flexure, and sometimes jejunal coils and the spleen, are displaced upwards through a congenital defect or traumatic rupture of the left leaf of the diaphragm. The appearances bear a considerable resemblance to those of Petit's eventration ; a domed air-space is seen in the left side of the thorax, bounded below by a horizontal fluid level, the dome showing reversal or absence of movement on respiration. Lung markings are seen through the air-space.

There are, however, two points which determine the nature of the lesion : (1) The upper limit of the dome is not formed by an

* Woodburn Morison, *Arch. of Radiol.*, 1923.

unbroken bowline, but shows some degree of irregularity owing to the multiple contents impressing their outline upon that of the hernial sac. (2) The horizontal fluid level lies above the normal level of the cardiac orifice (Woodburn Morison).

Administration of opaque fluid is not very helpful in differential diagnosis, except to render clearer the position of the horizontal fluid level and to determine the constituents of the domed air-space.

Massive collapse of the lung may result from trauma of the thorax or from diphtheritic paralysis of the diaphragm. It also occurs after abdominal operations, and it is possible that many cases of supposed postanæsthetic pneumonia are really instances of massive collapse.

The collapse usually involves the whole of one lobe (generally the lower lobe), but the entire lung may be affected. The collapsed portion presents on radiographic examination a fairly dense but uneven opacity. The heart and mediastinum are displaced towards the affected side, and the diaphragm, if not obscured by a basal opacity, is seen to be elevated and motionless.*

On the sound side a compensatory increase of translucency and of the diaphragmatic movements is apparent.

No radiographic distinction can be drawn between massive collapse and collapse due to obstruction of a bronchus.

Foreign bodies in a bronchus.—Apart from the opacity which may be produced by the foreign body itself, the radiographic appearances depend on—

(1) The degree of obstruction to the bronchus, and

(2) The presence or absence of infection of the pulmonary tissues.

Foreign bodies generally enter the right bronchus, and if of large size and recognizable opacity are often seen projecting into the bronchus from the lower end of the trachea. Small foreign bodies (e.g. a fragment of a tooth) may enter one of the lower divisions of the bronchus, and so appear at a considerable distance below and external to the hilum.

A large foreign body causing a considerable degree of obstruction to the main bronchus results in temporary over-distension and, later, collapse of the obstructed lung. At first, therefore, the affected side of the thorax shows increased translucency, with depression and limitation of movement of the diaphragm. The mediastinum is displaced towards the sound side, but shows inspiratory excursion towards the obstructed side. The temporary over-distension is followed by collapse if the obstruction is not relieved, the affected lung then showing a mottled opacity, the diaphragm being elevated, and the mediastinum displaced towards the affected side.

* Ritvo, *Amer. Journ. of Roent.*, N.S., 1924, xi. 337–42.

Onset of infection is signalized by the appearance of areas of much greater opacity in the collapsed lung. Should the main division of the bronchus to the lower lobe be seriously obstructed, the appearances of the affected lobe resemble those of the whole lung in obstruction of the main bronchus.

A foreign body lodged in one of the larger bronchi, but causing only a slight degree of obstruction, does not result in noticeable over-distension, although slight respiratory excursion of the mediastinum is usually observed ; nor does collapse necessarily follow. The incidence of inflammatory consolidation is then more readily apparent, and is usually seen to be of confluent broncho-pneumonic type. Abscess-formation and cavitation are frequently obscured by the density of the surrounding tissues.

Small foreign bodies lodged in one of the bronchioles result in no recognizable abnormality until the onset of infection has produced a broncho-pneumonic consolidation of the lobule involved. This may be followed by extension of infection, or may remain localized for long periods. A small deep-seated area of consolidation in the base of the lung should always arouse suspicion of a foreign body in a bronchiole.

Lipiodol injection of the bronchial tree.—This can be effected either through the larynx or by puncture of the crico-thyroid membrane ; whichever route is adopted, it is necessary to inject a small quantity of novocain or some similar local anæsthetic as a preliminary, otherwise the lipiodol tends to be expelled by coughing. No ill effects have been reported from the procedure.

So far as possible the injection is confined to the bronchial tree of one side only, the other side being injected on a subsequent occasion if considered desirable.

If it is intended to inject the whole tree of one lung, the patient is placed in a completely horizontal position and is turned about half-way on to the side to be examined. Should the lower lobe only require investigation, the patient is supported in a semi-sitting posture again inclined towards the affected side. It is impracticable to inject the upper or middle lobes alone. The quantity of lipiodol required for injection of a lower lobe only is about 5 c.c. ; for injection of the whole tree on one side 15–20 c.c. are needed.

Skiagrams obtained immediately after the injection show the larger ramifications of the bronchial tree as dense uniform opacities ; the terminal bronchioles are not filled, so that the peripheral zone of the lung contains no opaque striations. Within 20–30 minutes the uniform opacities undergo segmentation into small discrete rounded shadows, due to breaking-up of the lipiodol into globules. The radio-

graphic examination should therefore be conducted as expeditiously as possible.

The method is chiefly of value in demonstrating dilatations of the bronchi and cavities in the lung communicating with a patent bronchus. Deviations and strictures of the bronchi can also be shown.

Rapid elimination of the injected lipiodol takes place during the first forty-eight hours, but later becomes very slow, and is not completed until three to four weeks have elapsed.*

* Forestier and Leroux, *Journ. de Rad. et d'Electrol.*, 1923.

THE CARDIO-VASCULAR SYSTEM

WHILE it is true that X-ray examination of the great vessels has been practised to a considerable extent for many years, the accurate examination of these vessels, and more especially of the heart itself, has only of late become recognized as a useful method of investigation in cardio-vascular disorders. It is probable that this tardy advance in radiographic cardiology is due in part to the high degree of accuracy attained by clinical methods of examination, and in part to the difficulties of efficient radiology in this sphere. There can be no doubt, however, that systematic X-ray examination, carefully carried out, is capable of yielding a great deal of accurate information which should be of value to the clinician in diagnosis, prognosis, and treatment; while the technical difficulties have become greatly diminished with the improved types of apparatus now available.

There appears to be, in fact, no reason why radiology should not become as important in cardio-vascular disorders as in lesions of the respiratory and alimentary systems.

Methods of examination.—Two methods of examination have been elaborated, one of which depends on the screen image and the other on skiagrams. Many workers have adopted one or the other exclusively, but since each method possesses definite advantages it would appear more reasonable to utilize both.

The primary difficulty which must be surmounted by either method depends on the fact that the screen or plate shadows of the heart and great vessels, produced by irradiation at the usual distance of the subject from the tube, are distorted by the divergence of the rays.

In the fluoroscopic method of examination this difficulty is overcome by making a tracing of the cardiac and vascular outlines, each point on these outlines being marked as represented by the passage of the " central ray " from the tube. The resulting tracing is known as the orthodiagram, and should be an accurate outline, as regards both shape and size, of the cardiac silhouette. Distortion is obviated in the skiagraphic method by increasing the anodal distance to 6 (or sometimes 7) feet. At this range the radiations passing through

the heart and vessels are so little divergent as to render distortion of the image negligible.

Utilizing both fluoroscopy and the six-foot plate, systematic examination of the heart and great vessels can be carried out as follows :

The patient stands in the *postero-anterior position* behind the fluorescent screen, and a preliminary examination is made of the whole thorax. From this general view it should be possible to distinguish the habitus of the patient, and determine whether the shape of the cardiac opacity conforms to the particular type. (The general characteristics of the heart-shadow in different types of habitus have already been noted in Chapter X ; more detailed variations are described below, in considering cardiac mensuration.)

The patient is instructed to hold the breath in forced inspiration, and the position of the diaphragm on either side is marked, and also the position of the left border of the heart. The breath is then held in forced expiration, and these markings are repeated.

An accurate tracing of the left border of the heart and great vessels is then made, taking especial care to mark the junction on the outline of the left auricular appendage with the left ventricle. This point is of vital importance for subsequent measurements on the six-foot plate, but is frequently indistinguishable on the skiagram. On screen examination it will be seen that the left border of the heart presents an orderly pulsation corresponding to the left ventricle, above which is an area showing a '' rocking-bar '' movement. The junction of these two readily distinguishable segments is marked by a point known as the '' node of no motion.'' This designation, though useful, is somewhat deceptive, since the node is not stationary, but moves up and down over the lower part of the auricular area. The lowest limit of the node's travel is marked as the left auriculo-ventricular junction. Hence the tracing of the left border can be superimposed on the six-foot plate for the purpose of determining the exact position of this junction. There is no need to complete the tracing, as all other features of the silhouette are demonstrated sufficiently clearly, and often with greater accuracy, in the plate.

It will be noted that the actual excursion of the left margins of the heart on pulsation is very small—usually, in fact, no more than 2 mm. It has been found, moreover, that screen examination of the cardiac contractions is unsatisfactory as a means of investigation of rhythm, owing to this small marginal excursion and the complicated nature of the pulsations. A method of obtaining tracings of pulsation in the different chambers will be described later (*see* p. 150).

Finally, an orthodiagraphic measurement is made of the greatest internal transverse diameter of the thorax.

The patient is then turned into the *right anterior oblique* (first oblique) position, rotation being arrested when the shadow of the great vessels shows the narrowest transverse diameter. A tracing is made of the vessels in this position, and the posterior mediastinum is then examined for any sign of abnormal opacity. If any encroachment is noted on the mediastinum a plate is taken for confirmation.

Further examination in the *left anterior oblique* (second oblique) position is advisable if any abnormality is seen.

The patient is then brought forward to the plateholder, 6 feet from the anode of the tube.

The chest should rest squarely on the plate, and the breath is held in inspiration during the exposure. The tube is centred over the spinous process of the 6th dorsal vertebra.

It will be advisable here to consider the normal component parts of the silhouettes seen in the postero-anterior and the first and second oblique positions.

In the *postero-anterior view* the right side of the heart-shadow shows a curve which is formed entirely by the right auricle. Above this is a less marked convexity representing the right margin of the ascending aorta. The superior vena cava presents, as a rule, no recognizable opacity.

On the left side of the heart it is usually possible to demonstrate three convexities. The lowest and largest of these represents the left border of the left ventricle ; above this, and defined from it by the " node of no motion," is a small area of slight convexity representing the left auricular appendage; while above this again a small convexity is produced by the conus pulmonalis and pulmonary artery. The left border of the silhouette is completed above by the left margin of the aortic arch. (Plate 60, Fig. 1.)

In the *first oblique position* the right border of the cardio-vascular shadow is formed from above downwards by the posterior aspects of the aortic arch and descending aorta, the left auricle and the right auricle. The point of junction of these three parts is not very obvious, and it is usual to allocate roughly one-third of the right border to each. It is noteworthy that Bordet and Basquez, quoted by Martinez,* do not consider the upper third of this border to be formed by the descending aorta, but by the superior vena cava ; they state that the descending aorta crosses the upper part of the posterior mediastinal space obliquely to turn along the lateral aspect of the spine opposite the 4th dorsal vertebra, but that under normal conditions the vessel produces no recognizable opacity.

The left border of the shadow is formed from above downwards by the aortic arch and ascending aorta, the conus pulmonalis and

* *Amer. Journ. of Roent.*, 1921.

pulmonary artery, and the left ventricle. The three convexities produced by these structures can usually be differentiated. (Plate 60, Fig. 2.)

In the *second oblique position* the complete outline of the aortic arch is seen above. Below this the right border is formed by the right auricle and right ventricle, the auricle being represented by about the upper four-fifths, or rather more, of the border.

The left border is formed above by the left auricle, and below by the left ventricle, in about the proportion of 1 : 3.

The component parts of the borders in this view cannot be accurately delimited. (Plate 61, Fig. 1.)

The cardiac diameters.—Mensuration of the cardiac diameters is carried out on the six-foot plate. This must represent a true postero-anterior image, a condition which is verified by the symmetrical position of the inner ends of the clavicles in relation to the dorsal spine. The diameters are drawn on the plate, when dry, in pencil, as follows (Plate 61, Fig. 2) :

(1) The *mid-line* is drawn through the centre of the dorsal spinous processes.

(2) The *transverse diameter* is the sum of the maximum distances of the right and left borders from the mid-line. Two lines are therefore drawn perpendicularly on these borders (M.R. and M.L.).

(3) The *long diameter* (L.) is drawn from the most prominent point of the apex to the right border at the junction of the right auricle and aorta.

(4) The *diameter of the base* (B.) is the sum of $x + y$, which are drawn perpendicularly to the long diameter, from the most distant point of the outline on the right (x) and from the junction of the auricle and ventricle on the left (y).

The components of B. roughly divide the long diameter into an auricular portion lying above and to the right, and a ventricular portion lying below and to the left. This division has been utilized to formulate the auriculo-ventricular ratio, but since $x + y$ do not reach B. at the same point, no accurate determination of this ratio is possible.

(5) The *obliquity of the cardiac axis* is represented by the angle formed by the intersection of the transverse and long diameters.

(6) The *diameter of the aortic arch* is drawn transversely across the greatest width of the arch opposite the anterior extremities of the 2nd ribs.

Various additional measurements have been suggested, but the value of these has not yet been generally accepted.

Variations in shape and dimensions of the normal heart.—Habitus forms a most important factor in influencing the

shape and dimensions of the cardiac silhouette in normal individuals. The general characteristics of the cardio-vascular shadow in different types of habitus have already been noted in Chapter X.

Elevation of the diaphragm, either temporary or permanent, and obesity also produce modifications tending towards an increase of the diameter of the base and relative diminution of the long diameter, while to some extent similar changes occur in old age, even without obvious signs of arterio-sclerosis ; the transverse diameter of the aortic arch also undergoes considerable increase during middle and later life. A high diaphragm, too, is usually productive of an increased transverse diameter of the aortic arch.   Mills, quoted by Hirsch,* gives the following average measurements of the heart and vessels in the various types of habitus :

	Transverse Diameter	Long Diameter	Diameter of Base	Obliquity of the Cardiac Axis	Aortic Arch
Asthenic ..	8·8 cm.	11·4 cm.	9·9 cm.	48°	3·9 cm.
Hyposthenic	11·1 cm.	13·1 cm.	10·6 cm.	43°	4·8 cm.
Sthenic ..	12·4 cm.	14·1 cm.	10·6 cm.	37°	5·1 cm.
Hypersthenic	13·8 cm.	14·7 cm.	10·7 cm.	33°	5·7 cm.

It will be observed that the diameter of the base shows the least average variation of all the measurements recorded.

Estimation of volume.—Methods have been elaborated for estimating the volume of the heart from the silhouette area, the estimated volume then being compared with the average volume in a patient of the same age and weight, as computed in tables for the purpose.

It would appear that these estimations of volume are of little practical value, since no account is taken of the antero-posterior depth of the heart ; moreover, the heart volume shows considerable variations in normal individuals of the same age and weight, so that no rigid standard of comparison can be accepted as even generally applicable.

The large heart and the small (hypoplastic) heart.—For determination of cardiac enlargement in general terms, as opposed to enlargement of the different components of the heart, the cardio-thoracic ratio is accepted as accurate.   The value of this ratio is obtained by dividing the transverse diameter of the heart by the greatest internal transverse diameter of the thorax measured in inspiration, but is usually given for convenience as the percentage of the

former measurement to the latter. A ratio of more than 50 per cent. indicates cardiac enlargement.

In the initial stages of left ventricular enlargement, however, no variation will be found in the normal cardio-thoracic ratio, since the enlargement at this stage affects chiefly the postero-anterior diameter of the ventricle, without producing any appreciable modification of the postero-anterior silhouette. Morison and White * have devised means of estimating this increase in postero-anterior depth : The patient stands upright behind the screen, which is 60 cm. from the anode, and the tube is adjusted so that the central ray passes through the heart apex. A mark is made on the screen over the apex, and the tube is moved 10 cm. to the left. The shadow of the apex will be seen to lie to the right of its original position, and is again marked on the screen. This displacement of the apex shadow is known as the cardio-radiographic index, and is measured in milli-metres ; the displacement is the result of the obliquity of radiation which forms the marginal shadow after movement of the tube, and hence furnishes an indication of backward convexity of the left ven-tricle. The cardio-radiographic index of the normal heart varies from 7 to 14 mm. with an average of 10 mm. The highest abnormal index reported by the above authors is 42 mm. in a case of chronic nephritis.

This method offers an easy and accurate means of determining these enlargements at a stage when no clinical evidence of the abnormality is obtainable.

The *small* or *hypoplastic heart* presents a cardio-thoracic ratio of 38 or less. The hypoplastic heart is by no means always of the long vertical type, but may conform to the hyposthenic or even the sthenic form as regards obliquity of axis and relation of the cardiac diameters.

The determination of a small heart is of great importance when clinical examination reveals the presence of adventitious sounds, since by this means organic valvular disease is fairly conclusively disproved.

Beynard Smith† points out that a hypoplastic heart is usually found in individuals who suffer from long-continued symptoms of the " effort syndrome."

Pericarditis with effusion presents a problem of great difficulty to the radiologist, since the appearances closely simulate those of acute dilatation of the heart.

In both these conditions the cardiac opacity is enlarged and the distinction between the normal curves obliterated. Pulsation is greatly diminished or absent, and the lower two-thirds of the posterior mediastinal space, as seen in the first oblique position, is diminished

* *Arch. of Radiol.*, 1918-19.
† *Arch. Int. Med.*, xxv. 522-36.

in width or obliterated. In pericardial effusion, however, the shape of the cardiac opacity changes when the patient is placed in the supine position, while in dilatation no change in shape is produced by this means. Occasionally also a skiagram or even the fluoroscope reveals the shadow of the heart inside that of the effusion. It is often stated that the cardio-phrenic angle (the angle formed by the junction of the right auricle with the diaphragm in the postero-anterior silhouette) becomes obtuse in cases of pericardial effusion, but other workers have recorded an increase in acuity of the angle in this condition, which is in accordance with the author's own observations. It would appear from this conflict of opinion that no definite significance can be attached to variations in the cardio-phrenic angle as regards differential diagnosis. (Plate 62, Fig. 1.)

Adhesive pericarditis.—In the slighter forms of this lesion the X-ray examination is usually quite inconclusive. Extensive adhesions between the visceral and parietal pericardium may result in obliteration of pulsation and also of the normal curvatures, the left border approximating to a straight line, and the silhouette tending to become triangular in shape.*

Should adhesions form between the pericardium and the mediastinal pleura, the excursions of the left border are diminished. This can be determined by observation of the respiratory excursion of the left border, which normally measures 3 cm., and also by obtaining six-foot postero-anterior plates of the patient lying on the left and then on the right side, the left border of the heart showing a displacement of 3 cm. in the normal individual as a result of this change in posture.

Congenital diseases of the heart.—The recorded examinations of these lesions are insufficient in number to warrant any detailed description. In every instance considerable general cardiac enlargement has been noted; in patent ductus arteriosus and in pulmonary stenosis there are prominence and increased pulsation in the convexity representing the pulmonary artery, and apparent enlargement of the right ventricle. As will have been noted, this latter chamber does not enter into the outlines of the postero-anterior or first oblique silhouettes, and only forms a very small portion of that of the second oblique position. Enlargement of the right ventricle is usually inferred, however, if in the absence of obvious auricular enlargement—i.e. prominence of the auricular convexities —the diameter of the base shows a definite increase in length.

Valvular diseases.—Acquired valvular disease has been the subject of fairly extensive radiographic study; characteristic changes in shape and size can be recognized in isolated lesions, but

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* Martin, *Amer. Journ. of Roent.*, N.S., 1921, viii. 259–68.
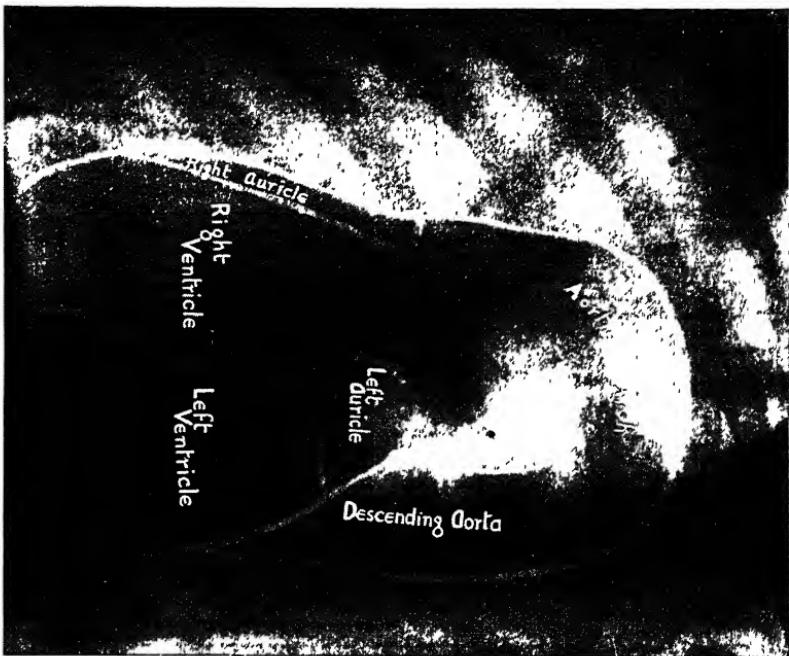
Fig. 1.—Components of cardiac silhouette. Second oblique position.

L. = Long diameter
M.R.+M.L. = Transverse diameter
x. + Y = Diameter of Base (B.)
Ao. = Diameter of Aorta.

Fig. 2.—Cardiac diameters.

Fig. 1.—Components of cardiac silhouette. Postero-anterior position.
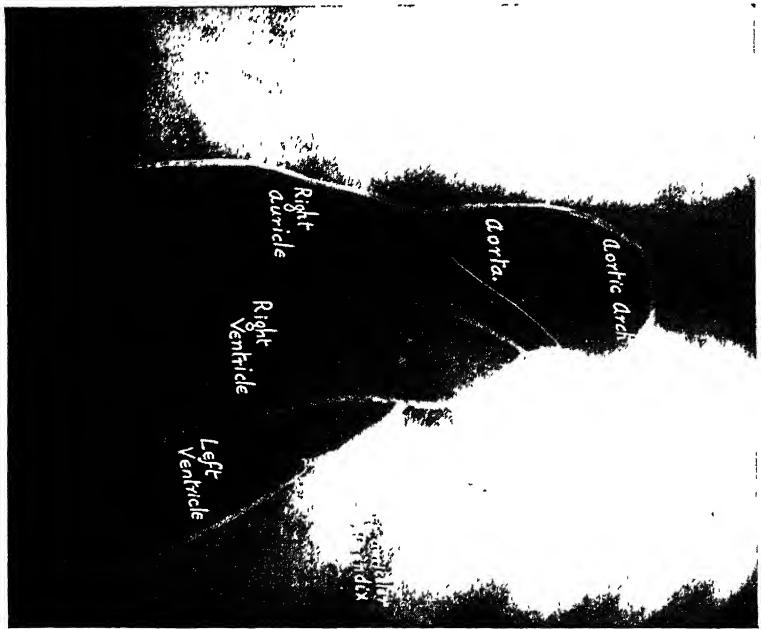
Fig. 2.—Components of cardiac silhouette. First oblique position.
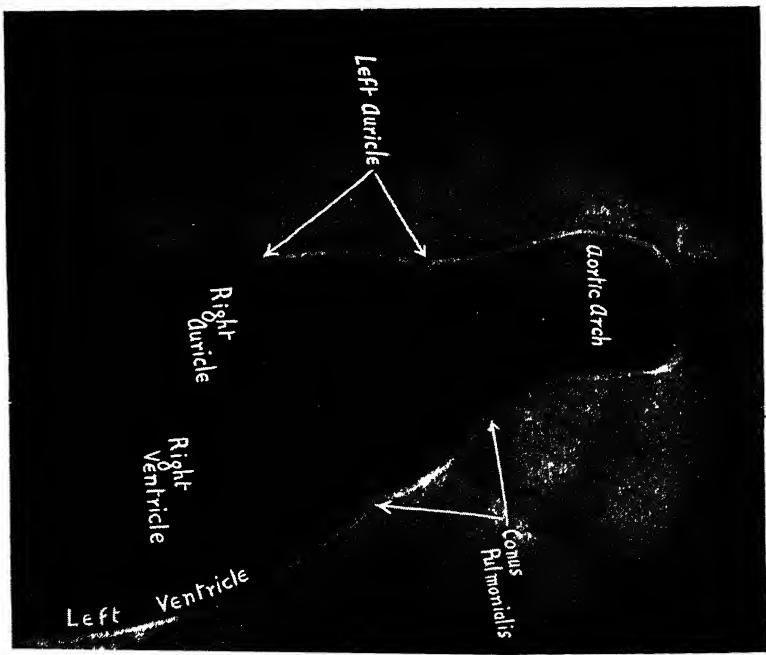
Fig. 1.—Pericardial effusion.

M.L.

M.R.
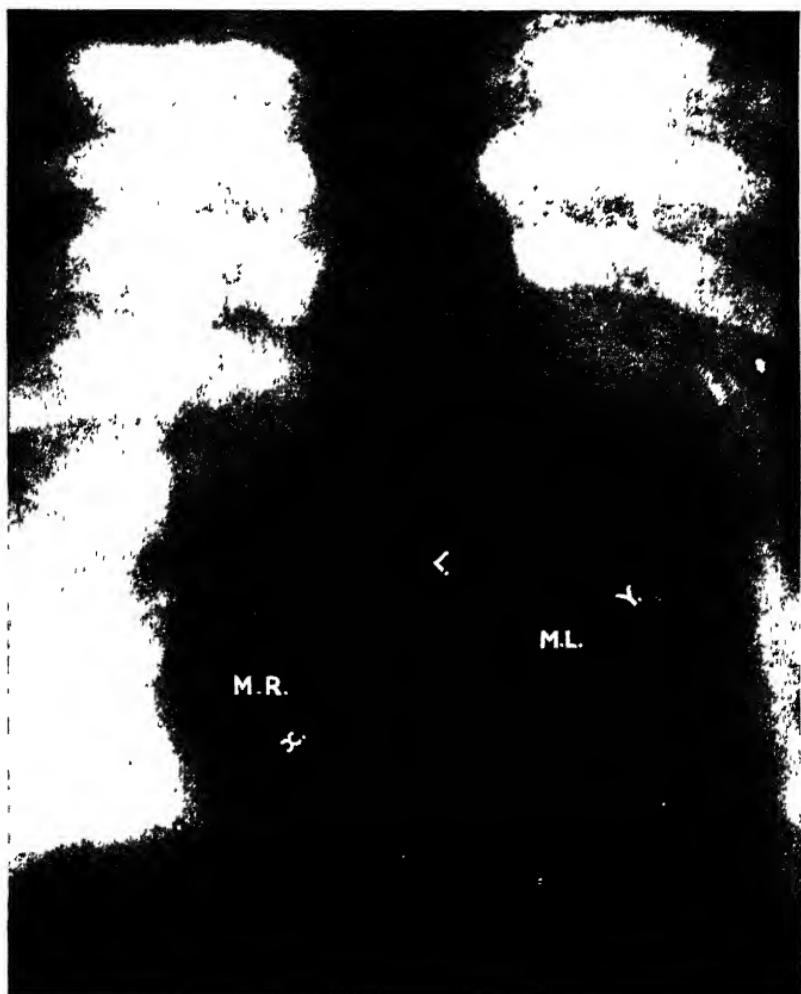
Fig. 2.—Mitral stenosis and regurgitation.

PLATE 62.
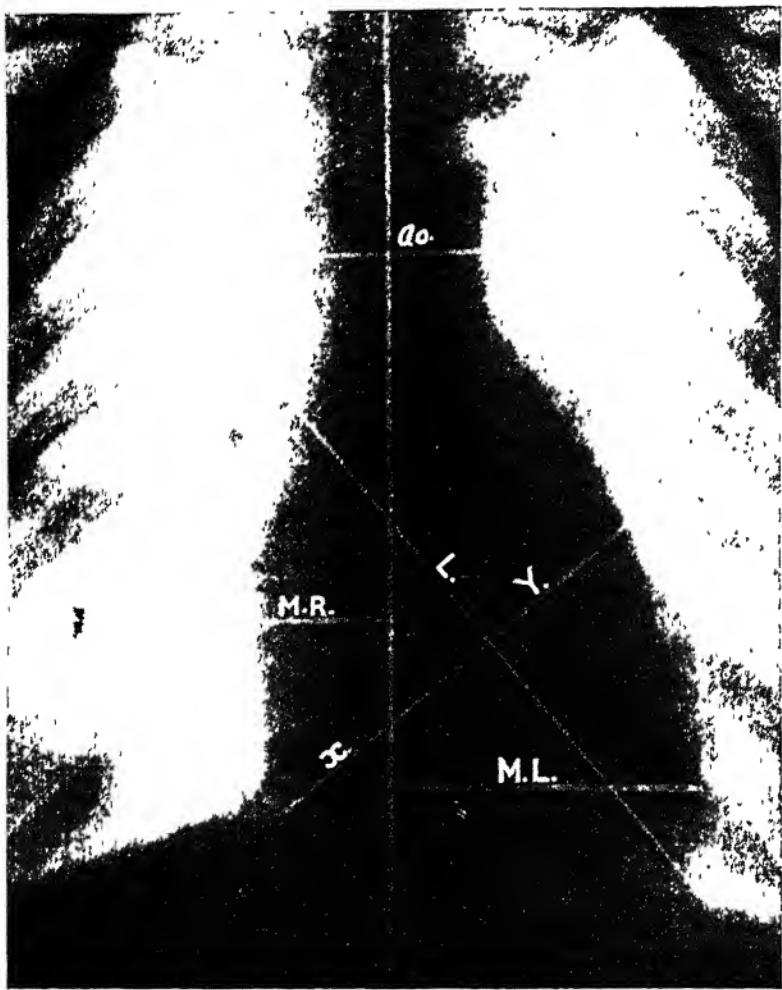
Fig. 1.—Pure mitral stenosis.

Fig. 2.—Fusiform aneurysm of aorta.

PLATE 63.

it must be remembered that other conditions may result in very similar appearances, and also that valvular affections are often complex. It is, in fact, unjustifiable to make a detailed diagnosis from the X-ray appearances alone, but that exceedingly valuable information can be obtained by this means is undeniable.

The mitral heart.—In mitral disease the left border of the heart tends to assume a "step-ladder" outline, owing to increased prominence of the curves formed by the left auricle and pulmonary artery. At a late stage enlargement of the left auricle constricts or entirely obliterates the middle third of the posterior mediastinal space, and eventually this chamber may form part of the right border of the postero-anterior silhouette. In pure stenosis the left ventricular curve shows little if any increased prominence, and the cardio-thoracic ratio for a time remains practically normal, this being the only valvular lesion in which the ratio is not appreciably raised.

In cases of combined mitral stenosis and regurgitation the left ventricle undergoes some enlargement at a fairly early stage. In both forms of lesion back-pressure results in enlargement of the right ventricle and right auricle, with marked prominence of the right auricular convexity.

As a result of these changes the diameter of the base and the transverse diameter are markedly increased. The long diameter may be increased (indicating enlargement of the left ventricle), but this is not usually a striking feature. The diameter of the base, in fact, approaches, or may even equal in length, the long diameter, a condition which occurs in no other cardiac lesion. The "round heart" is characteristic of mitral stenosis and regurgitation (Plate 62, Fig. 2), while the "boxing-glove" heart typifies a pure mitral stenosis, this latter deformity resulting from enlargement of all the chambers except the left ventricle. (Plate 63, Fig. 1.)

The hilar and perihilar shadows are generally increased in size and density, due to dilatation of the pulmonary vessels, and the whole lung structure presents a hazy appearance, probably as a result of stasis in the pulmonary circulation.

Aortic disease.—Pure aortic stenosis is apparently very rare. The ventricles are enlarged, especially the left, with resulting increase in the long and transverse diameters, and prominence of the ventricular portion of the left border. The aortic diameter is not enlarged, and may even appear unduly small. It is not possible to differentiate this condition from the cardiac enlargements of chronic renal disease or myocarditis.*

Aortic regurgitation is usually associated with enlargement of the aorta from preceding aortitis.

* Martin, *Amer. Journ. of Roent.*, N.S., 1921, viii. 259–68.

The ventricles may show considerable enlargement, especially the left, and the left ventricular curve becomes unduly prominent. These changes result in a marked increase in the long and transverse diameters, with only very slight increase in the diameter of the base. The term " horse-shoe heart " is used to describe the postero-anterior silhouette of aortic disease.

In combined mitral and aortic disease the characteristic forms are lost, and the heart shows an enlargement of all the chambers with increase in all the diameters. The cardio-thoracic ratio becomes very high.

Cardio-renal disease.—In the cardiac hypertrophies of chronic nephritis the enlargement affects both ventricles. Therefore the long diameter is increased, and also the diameter of the base, the normal convexities of the auricular contours indicating that this latter abnormality is due to enlargement of the right ventricle. The ventricular portion of the left margin shows considerable prominence, with resultant increase in the cardio-thoracic ratio. Pulsation is generally vigorous, and the transverse diameter of the aorta is increased. The enlarged heart of myocarditis shows similar characteristics, except that pulsation is commonly diminished.

Hence it will be seen that a lesion limited to the mitral valve produces changes in shape and in the relative length of the diameters which may fairly be described as characteristic ; the radiographic appearances in aortic disease, on the other. hand, cannot be distinguished with any degree of certainty from those due to chronic nephritis or myocarditis.

Increased width of the great vessels.—An increase in the transverse diameter of the aorta may be produced by specific aortitis resulting in fusiform or saccular aneurysm, by cardio-renal disease, and by arterio-sclerosis. It has already been noted that some increased width of the great vessels is commonly seen in very obese subjects and those with a high diaphragm. Prominence of the conus pulmonalis and pulmonary artery, from mitral disease, pulmonary stenosis, or pulmonary aneurysm, may simulate aortic dilatations. In mitral disease the typical round or boxing-glove shape of the heart usually renders clear the nature of the increased shadow ; while in the rare conditions of pulmonary aneurysm or stenosis the localized knob-like projection to the right of the lower part of the vascular opacity is generally fairly characteristic.

Arterio-sclerosis. — Martin* points out that the increased width of the vascular shadow in this condition is not due to any marked dilatation, but to a swinging of the descending aorta

* *Amer. Journ. of Roent.*, 1921, N.S., viii. 259–68.

Arterio-sclerotic aorta.

PLATE 64.

to the left ; this can be confirmed by rotating the patient into the first oblique position, when the superimposed shadows of the ascending and descending aorta will be seen to present a diameter which falls within normal limits (30–35 mm. at age 65). Pulsation is diminished and the opacity of the vessel tends to be increased, while the " knob," or projection to the left, normally seen at the summit of the adult aortic arch, is unusually prominent. (Plate 64.)

˅ Syphilitic aortitis in its earliest stages presents no radiographic abnormality. The further progress of the disease results in an increase in the transverse diameter which it may be impossible to distinguish from the widened shadow of arterio-sclerosis or cardiorenal disease. In both aortitis and cardio-renal disease the dilated vessel shows increased pulsation and enlargement in both postero-anterior and first oblique diameters, while in arterio-sclerosis pulsation tends to be diminished and the first oblique diameter is frequently normal.

Localized enlargements, especially those on the right side of the aorta immediately above the aortic valves, are generally indicative of aortitis.

Aortic aneurysm. — No clear dividing line can be drawn between the earlier dilatations of specific aortitis and the later development of fusiform or saccular aneurysm, the latter being, in fact, merely an advanced stage of the former.

Dilatations, however, which have attained a magnitude meriting the designation of fusiform aneurysm, and to a still greater degree the localized dilatations of saccular aneurysm, present great difficulties in radiographic diagnosis.

The opacity of aneurysm is seen to occupy and extend to one or both sides of the superior mediastinum ; the opacity may also extend upwards, and in this connexion it is important to note that the upper border of the aortic arch normally lies about 2 cm. below the upper border of the left clavicle.

The margins of an aneurysm are smooth and clearly defined ; the outline is generally regular and shows expansile pulsation.

The appearances may be closely simulated by mediastinal neoplasm, the enlarged glands of tuberculosis, Hodgkin's disease or lymphatic leukæmia, a persistent thymus, or an intrathoracic lobe of the thyroid. These conditions can be clearly distinguished from aneurysm if the shadow of a normal aorta can be demonstrated ; definite absence of expansile pulsation is also of value in excluding aneurysm. (*See* p. 131.)

In some instances the appearances are so anomalous that no definite diagnosis is justifiable ; and errors are not infrequent even in cases which appear fairly characteristic in their radiographic features. (Plate 63, Fig. 2.)

The X-ray cardiogram.—The investigations detailed above are directed towards the size and shape of the chambers of the heart and of the great vessels; attempts are being made to obtain radiographic tracings of pulsation analogous to the electro-cardiogram, and it is hoped that by improved technique and more extensive experience accurate information of the cardiac function may be forthcoming.

Briefly, the method is as follows: Strips of lead are arranged on the chest, leaving transverse slits 2 mm. in width over the pulsating margins of the left ventricle, aorta, and pulmonary artery. A plate or film is moved at a uniform rate of about 5 cm. per second across this lead covering and intervening slits, from above downwards. In this way a radiographic record is obtained of the pulsations in the parts below the slits. Technical difficulties have retarded the development of this method, and no definite indication can at present be given as to its ultimate value.

The peripheral vessels.—*Aneurysm* of the peripheral vessels rarely produces a recognizable opacity on X-ray examination. *Calcification* of the arteries in the limbs and of the extracranial arteries of the head is readily demonstrated, the affected vessels appearing as tortuous, cylindrical, mottled opacities, clearly differentiated from the surrounding soft tissues.

Nævoid tumours sometimes show multiple small rounded opacities in their substance, indicative of calcified thrombi.

CHAPTER XV

THE ALIMENTARY TRACT

The Salivary Glands

The salivary glands are of interest to the radiologist in view of the occasional formation of **salivary calculi.** These calculi are composed largely of calcium phosphate and carbonate, and therefore present considerable opacity to X-radiation ; failure to demonstrate an abnormal shadow in the region of the glands or their ducts may be regarded as fairly conclusive proof that no calculus is present. The opacities are generally uniform in density, but may show a central area of relative translucency.

Calculi are most commonly found in the *submaxillary gland* or its duct (Wharton's duct). A calculus embedded in the gland appears in a lateral skiagram of the skull superimposed over the shadow of the mandible, or just below the lower border of that bone, opposite the molar teeth ; the opacity may be rounded, or irregular in shape. A calculus lying in *Wharton's duct* appears in such a skiagram over the shadow of the mandible and roots of the premolar or canine teeth ; if situated at the anterior extremity of the duct the calculus may appear above the alveolar process of the mandible, the exact situation depending on the position of the tongue. Confirmation of the presence of a calculus in Wharton's duct can be obtained by placing a film or small plate horizontally in the mouth on top of the tongue and directing radiation upwards to this from below the mandible. Calculi situated in the duct are generally quite regular in outline, and round or oval in shape. (Plate 65, Fig. 1.)

Parotid calculi are rare ; if situated in the gland they are seen in a lateral skiagram of the skull over the posterior part of the ascending ramus of the mandible, or between the ascending ramus and the mastoid process. Should the calculus occupy *Stenson's duct* the opacity will lie over the neck or crown of one of the upper molar teeth, or in a horizontal plane continued back from these teeth across the ascending ramus of the mandible nearly to its posterior border.

As in the case of submaxillary calculi, the calculus formed in the parotid gland is round or irregular in shape, while that in the duct is round or oval.

Sublingual calculi are apparently very rare. They would be seen in a lateral skiagram lying over the roots of the premolar or canine teeth, below the level of Wharton's duct. Radiography with a probe passed down this duct would probably be necessary to determine the situation of the calculus with any degree of certainty.

THE TEETH

Radiography of the teeth and surrounding alveoli has assumed a position of great prominence of late years, in view of the importance now attached to dental sepsis, since by no other means may it be possible to determine the extent, or indeed the presence, of peridental infection.

The value of dental radiography is not, however, confined to the detection of infective processes arising in connexion with the teeth ; in developmental abnormalities also and in hidden caries the skiagram usually provides unimpeachable evidence.

It appears advisable to point out that correct interpretation of dental skiagrams is by no means easy, and requires, for its successful performance, a sound general knowledge of radiological diagnosis.

Normal radiographic appearances.—The normal *alveolar process*, either maxillary or mandibular, presents the usual appearance of cancellous bone, enclosed by a thin cortical layer of compact structure. In the usual dental films this compact layer is seen at the free margin of the alveolar process between the teeth, and is also continued downwards to form the lamina dura of the tooth-sockets. The lamina dura can be traced around the entire extent of the roots as an unbroken layer of condensed bony tissue of the same thickness as the cortex of the alveolar margin. The junction of the marginal cortex and the lamina dura forms an abrupt angle on either side of the neck of the tooth.

The cancellous structure of the alveolar processes is modified in the upper molar and premolar regions by the frequent superposition of the lower part of the maxillary antrum, which presents a translucent area with a clearly-defined lower margin of cortical bone ; and in the upper incisor region by the shadows of the intermaxillary suture and anterior naso-palatine foramina. In the lower jaw the inferior dental canal is often plainly seen, and also the mental foramen, this latter producing a small round translucent area in close relationship to the apex of the 2nd premolar tooth.

The *teeth* present an opacity to X-radiation much greater than the surrounding alveolus. This opacity is not equal over the whole of the tooth : the enamel can be distinguished from the underlying dentine by reason of its greater density ; the dentine cannot be distinguished, however, from the cement, or crusta petrosa. All

Fig. 1.—Salivary calculus.

Fig. 2.—Normal teeth.

Fig. 3.—Normal temporary and developing
permanent teeth.

Fig. 4.—Follicular odontome containing inverted lower wisdom-tooth.

PLATE 65.

these three tissues appear in the skiagram devoid of structural detail.

The central portion of the crown presents a translucent area representing the pulp cavity, and varying in shape and size with the different teeth. This central translucency is continued through the neck and roots, gradually diminishing in width in the fully formed tooth as the apex is approached ; occasionally the dental canal, piercing the extremity of the root, can be demonstrated, but usually the central translucent area terminates 2–3 mm. from the apex.

The surfaces of the whole tooth and the margins of the pulp cavity are perfectly smooth and defined.

In a developing tooth these appearances are modified, the walls diverging so that the central translucency is widest in the deeper portion of the tooth and is directly continuous with a translucent zone which surrounds the whole tooth and represents the dental sac.

The outer boundaries of the dental sac are accentuated by a slight linear condensation of the alveolus, which in the fully formed tooth is represented by the lamina dura of the socket. As development of the tooth proceeds, the newly formed walls of the root show gradual approximation, but still diverge at their extremities when eruption takes place. " Closure of the apex," representing the completion of development and formation of the fine dental canal, is not observed for a variable period after eruption.

In the skiagram of a fully developed tooth, a very fine translucent zone is seen separating the root from the lamina dura of the socket. This zone is continued around the apex, and is of equal width in every part of its course ; it represents the periodontal membrane.

In the developing unerupted tooth this zone is seen to be of greater width, and representative of the dental sac. (Plate 65, Figs. 2, 3.)

Ages at which the teeth can first be recognized.— The age at which calcification is sufficiently advanced to render the different unerupted teeth apparent in a skiagram is subject to slight individual variations in normal subjects. The following figures must therefore be regarded as approximate only :

At birth all the deciduous teeth are visible. Very soon after birth the 1st permanent molars can be distinguished. At the end of the first year all the permanent incisors and canines are visible.

At the end of the third year all the permanent 1st premolars are visible, and at the end of the fourth year all the permanent 2nd premolars and 2nd permanent molars.

At the end of the eleventh year all the 3rd permanent molars are visible.

Abnormalities of the Teeth and Alveoli

Developmental abnormalities are very common. One or more of the permanent teeth may be *absent*, or eruption may be delayed ; in the latter case the tooth is frequently misplaced, sometimes to a considerable extent. This is most often seen in the upper and lower canines, and in the lower 3rd molars. The last-named teeth frequently show impaction either in the ascending ramus or against the 2nd molar. Impaction against the 2nd molar results from obliquity of the long axis of the wisdom tooth ; sometimes the long axis is practically horizontal and the crown looks directly forwards.

Lower wisdom teeth occasionally develop in a situation far removed from their proper position, and may be found in any part of the ascending ramus, or even in the coronoid process of the mandible. Extra-oral skiagrams are therefore necessary to exclude the presence of a mandibular 3rd molar which is not revealed by the ordinary dental film. *Supernumerary* teeth less often require radiological investigation, although a skiagram may be of value in determining the choice of extraction.

Follicular odontomes are seen as translucent cystic areas, rounded or oval in shape, and with a perfectly defined margin of slightly condensed bone ; projecting into the cyst is seen a tooth, often so deformed as to bear little resemblance in shape to the normal structure. (Plate 65, Fig. 4.) The diagnosis of follicular odontomes, as distinct from other cysts of the jaws, depends upon the recognition of this retained tooth.

Composite odontomes present dense opacities of irregular shape lying in, but showing no distinct continuity with, the alveolus. Small composite odontomes, whose presence gives rise to no clinical manifestations, are not very uncommon, and are usually seen lying in the premolar region just below the alveolar margin. Large composite odontomes are quite rare.

Epithelial odontomes are more common in the mandible than in the maxilla. They present multilocular cystic cavities which may involve a great part of the horizontal ramus on one or both sides. The diagnosis from other cystic conditions depends on the definite multiloculation and the absence of any unerupted tooth in connexion with the cyst. (Plate 66, Fig. 1.) Large unilocular cysts are sometimes seen in the ascending ramus of the mandible ; some of these are follicular odontomes connected with a misplaced unerupted 3rd molar tooth, but in other instances there is no retained tooth, and the cyst is generally regarded as an epithelial odontome. (Plate 66, Fig. 2.)

The **alveolar processes** sometimes show diffuse or localized

Fig. 1.—Epithelial odontome of mandible.

Fig. 2.—Epithelial odontome in ascending ramus of mandible.

PLATE 66.

hypertrophy of developmental origin. As in similar conditions affecting other parts of the skeletal system, the skiagram shows no abnormality in structure.

Dental caries.—A carious cavity is represented in the skiagram as a rounded or irregular translucent area with smooth margins in the crown or neck of the tooth. If the cavity is seen in profile the translucent area is continuous with a defect in the wall of the tooth, and the diagnosis is at once obvious. Should the cavity originate in the inner or outer aspect of the tooth, however, the translucent area will appear more centrally situated, and the defect in the surface of the tooth, not being seen in profile, will not be apparent. Small cavities so placed, and seen superimposed upon the translucency of the pulp-cavity, are very readily overlooked. (Plate 67, Fig. 1.)

It must be remembered also that while gold and amalgam fillings are densely opaque to X-radiation, porcelain fillings are very translucent, as compared with the surrounding tooth ; it is impossible to state from the skiagram, therefore, whether a small round cavity is unfilled or contains a non-opaque stopping. A cavity with irregular walls is certainly unfilled. Caries below an opaque filling is recognized as a translucent zone separating some part of the filling from the normal tooth opacity.

Inflammatory lesions connected with the teeth may be confined to the tooth itself (e.g. pulpitis), in which case the skiagram is not always of service ; or may originate in or extend to the periodontal membrane ; or may involve the alveolus by extension from either of these structures. It is important to bear in mind that infection of the alveolus from the tooth necessitates infection of some part of the periodontal membrane also ; this fact is of great value in the recognition and exclusion of periapical lesions.

Acute pulpitis is unaccompanied by any changes in the radiographic appearances ; similarly, the absence of abnormality in the skiagram does not exclude the possibility of chronic pulpitis. Not infrequently, however, this chronic inflammatory lesion results in gradual calcification of the pulp, with resultant constriction or even obliteration of the translucent area representing the pulp-cavity. Localized calcareous deposits may also occur, with the production of " pulp-stones," these being shown in the skiagram as small rounded opacities in the pulp-cavity. It may be noted, however, that the causal relationship of chronic pulpitis to the formation of pulp-stones is a matter of some dispute.

Acute periodontitis produces no recognizable abnormality in the skiagram.

Chronic periodontitis.—Radiographic examination is of the greatest value in this disease ; not only can the extent of lesions which

have been recognized clinically be determined, but periodontal inflammation which presents no clinical manifestations is not infrequently discovered.

For descriptive purposes chronic periodontitis may be said to belong to the *marginal* or to the *generalized* type. These terms merely indicate the location of the radiographic changes seen around any one tooth : they have no reference to the numerical extent of the disease ; either type of lesion may involve one or many teeth, and in advanced cases it is often impossible to distinguish the original form of the affection.

Marginal chronic periodontitis.—In this type of disease the earliest change to be seen radiographically is a destruction of the angle formed by the junction, around the neck of the tooth, of the lamina dura with the alveolar cortex.

As a result of this cortical destruction two abnormal conditions are observed : (1) the superficial part of the root is no longer enclosed in the socket, and (2) the abrupt angle formed by the two cortical layers is replaced by an oblique cancellous surface. (Plate 67, Fig. 2.)

This marginal destruction is progressive in active disease, erosion of the socket and of the adjacent alveolus gradually extending until, in very advanced cases, the tooth appears to stand in a wide trough. (Plate 67, Fig. 3.)

Usually, in less advanced cases the periodontal membrane lining that portion of the socket which remains intact shows no radiographic changes—i.e. it is seen as a thin linear translucent zone of uniform width around the apex of the tooth. Sometimes, however, the superficial one or two millimetres of this translucent zone is of slightly increased width, indicating a localized thickening of the periodontal membrane preceding the bony destruction.

The marginal erosion of bone is not generally associated with any deep-seated change in alveolar structure, nor any alteration in the appearance of the tooth. Arrest of the disease (as regards bone destruction) is signalized by superficial condensation of the exposed cancellous tissue ; the compact layer of bone thus formed is thicker and more dense than the original alveolar cortex. There is no restoration of bone which has been destroyed. (Plate 67, Fig. 4.)

It is often possible, therefore, to state from the radiographic appearances whether bone destruction is progressive or has become arrested ; but that is all. It is for the clinician to determine the presence or absence of active inflammation in the soft tissues around the exposed portion of the root—the skiagram provides no information on this point.

Generalized chronic periodontitis.—In this type of disease the early changes consist in a fairly uniform thickening of the perio-

Fig. 1.—Cavity in tooth.

Fig. 2.—Chronic periodontitis.

Fig. 3.—Very advanced marginal periodontitis.

Fig. 4.—Marginal periodontitis. Bone destruction arrested.

Fig. 5.—Generalized form of chronic periodontitis.

Fig. 6.—Dilated lymphatic spaces.

Fig. 7.—Apical osteitis.

Fig. 8.—Dental cyst.

PLATE 67.

dontal membrane around the whole extent of the root; this is shown in the skiagram by increased width of the translucent zone between the root and the lamina dura. Marginal destruction is usually entirely absent, although it may appear at a late stage of the disease. The lamina dura of the socket, on the other hand, commonly shows increased thickness and density indicative of sclerosis, and chronic inflammatory changes are often seen in the surrounding cancellous tissue, consisting of a diffuse lamellar sclerosis with some resultant loss of structural detail. These generalized alveolar changes are most marked when several adjacent teeth are affected by this type of periodontal disease. (Plate 67, Fig. 5.) The outline of the root also tends to show irregularities resulting from localized deposition of opaque salts; and sometimes localized bony expansions occur, especially at the apex, in which situation they form the so-called apical osteomata.

Repeated examinations show that this form of disease often remains stationary for long periods, although slowly progressive sclerosis of the alveolus may be demonstrated. Sometimes marginal destruction supervenes, and, if this is extensive at the first examination, it may be impossible to determine the original type of lesion.

Calcification or ossification of the periodontal membrane may occur, with obliteration of the translucent zone around the root, and completion of this process probably indicates arrest of active inflammatory disease.

Dilatation of the alveolar lymphatics in periodontal disease.—In some cases of chronic marginal periodontitis vertical channels are seen in the alveolus between the teeth, passing from the margin to the deeper parts of the bone, where anastomotic loops are formed; in the mandible these channels join the inferior dental canal. (Plate 67, Fig. 6.) It is thought that these appearances are produced by dilatation of the lymphatics.

Alveolar changes in old age.—In elderly subjects considerable absorption of the alveolar margin, with resultant exposure of the roots of the teeth, is commonly seen. This condition can generally be distinguished from marginal absorption due to inflammatory disease: the absorption of old age is unaccompanied by any exposure of cancellous tissue; the alveolar cortex still joins the lamina dura at an abrupt angle, and no breach is seen at this point in the continuity of compact bone. The appearances, in fact, are normal except that less of the root is contained in the alveolus than is the case in earlier life.

Apical osteitis. — Periapical inflammation may be acute or chronic.

Acute apical osteitis in its earliest stages cannot be recognized in the skiagram. In the vast majority of cases, however, sufficient

time has elapsed since the onset of symptoms for definite radiographic changes to have occurred. The skiagram then shows an ill-defined area of rarefaction and loss of detail in the alveolus contiguous with the apex of the affected tooth, and an area of destruction in the peri-apical portion of the lamina dura. The observation of this latter abnormality is essential for correct diagnosis ; a tooth which shows a perfectly normal lamina dura and normal translucent periodontal zone is not the subject of periapical inflammation, although an apparently rarefied area may overshadow the apex. It is only by insistence upon this fact that frequent mistakes can be avoided. As previously noted, the apices of teeth may be seen superimposed upon the mental and anterior naso-palatine foramina, or on the floor of the antrum ; recognition of an intact lamina dura and periodontal membrane absolves the tooth from any suspicion of apical inflammation in such circumstances. Similarly, an area of apical osteitis may extend backwards or forwards around the socket of the adjacent tooth ; an intact lamina dura encircling the root indicates that the second tooth is overshadowed in the skiagram by the alveolar changes but is not involved in them, while a breach in the lamina dura proves that both teeth are affected.

In the later stages of acute apical osteitis the bony changes become definitely circumscribed by the development of a slightly condensed linear margin, and a small structureless opacity may be seen within the rarefied area indicative of sequestrum-formation. The apex of the root not infrequently undergoes some amount of absorption. The degree of alveolar rarefaction attained in these cases is never very extreme, unless, as occasionally happens, the infection leads to a diffuse osteo-myelitis of the mandible or maxilla ; nor does the rarefied area show a smooth rounded outline ; it is usually possible, therefore, to distinguish the acute from the chronic type of periapical inflammation, at whatever stage of the disease the patient may be first seen.

Chronic apical osteitis.—The first recognizable change in the development of chronic apical osteitis consists in thickening of the periodontal membrane around the apex of the tooth, with a resultant localized increase in width of the translucent periodontal zone. This process is slowly progressive, with the ultimate formation of a round translucent area immediately adjacent to the apex of the tooth. This area is directly continuous in the skiagram with the periodontal zone, the apical portion of which it replaces, and is bounded by a continuous layer of slightly condensed bony tissue which is in unbroken continuity with the lamina dura. The appearances, in fact, suggest a pouching of the lamina dura. (Plate 67, Fig. 7.) In point of fact, the peri-apical translucency represents an encysted granuloma which causes local erosion of the lamina dura and underlying cancellous tissue, but this erosion is concealed by the simultaneous formation of reactionary

condensation around the margins of the lesion. The apex of the tooth frequently shows a slight degree of absorption.

The inflammatory process tends to remain stationary for long periods. Sometimes an exacerbation may lead to suppuration, clinically resembling an acute apical osteitis; or the granulomatous tissue may increase and liquefy, with the production of a dental cyst. Not infrequently the lesion heals; the skiag·am then shows a faint ring of condensation around the apex enclosing an area of normal or very slightly rarefied cancellous bone.

Dental cysts arise by transformation of chronic apical granulomata. They may attain a considerable size and, unless treated, may continue to enlarge after removal of the infected tooth. The radiographic distinction between dental cyst and apical granuloma depends solely on the size of the translucent area, a true granuloma rarely exceeding ¼ inch in diameter.

Dental cysts must be distinguished from other cystic conditions of the jaws.

The characteristic features of a dental cyst are: (1) The apices of one or more teeth project directly into the cavity, unless extraction has preceded radiography. (Plate 67, Fig. 8.) (2) If the causative tooth has been removed, a fragment of the apex, or a structureless opacity suggestive of a sequestrum, may be seen in the cavity. In addition: (3) Follicular odontome is excluded by the absence of any retained tooth. (4) Epithelial odontomes are commonly multilocular, while dental cysts are unilocular.

Diffuse osteomyelitis, in the acute form, usually originates from an acute apical osteitis. The radiographic appearances are identical with those of similar lesions elsewhere in the skeletal system. A peculiar form of chronic osteomyelitis is sometimes seen in the premolar and molar regions of the ·maxillary alveolar process, as a result of chronic periodontal or apical infection. The affected portion of the alveolus undergoes progressive enlargement, not necessarily arrested by extraction of the teeth. The skiagram shows diffuse, ill-defined areas of sclerosis and rarefaction with widespread loss of structural detail. Sequestra of considerable size may be demonstrated. The remarkable feature of this condition is the absence of any sinus-formation, the swelling simulating, on clinical examination, a simple hypertrophy or a neoplasm.

Peridental infection in relation to remote disorders. —Considerable difference of opinion appears to exist as to the relative importance of periodontal and periapical infections in general or remote disease. It is perhaps impossible to state which form of lesion is more commonly found in causal relationship with such diseases; but it can be confidently ̦affirmed that both chronic periodontitis, of

either type described above, and chronic apical osteitis are equally *capable* of acting as foci of infection, and must therefore be regarded with equal gravity.

Caries, unless associated with some type of peridental infection, does not appear to constitute a focus for the production of remote disease.

"**Dead**" **teeth** can be recognized in the skiagram (1) if apical osteitis is present, (2) if an opaque filling is seen in the pulp-cavity, (3) if a large portion of the crown has been destroyed by caries, with extensive involvement of the pulp-cavity. Otherwise a dead tooth presents no point of radiographic distinction whatsoever from the vitalized structure.

THE ALIMENTARY TRACT (*continued*)

THE OPAQUE MEAL AND OPAQUE ENEMA

THE hollow viscera comprising the alimentary tract present no opacity to X-radiation which enables them to be distinguished from the surrounding soft tissues ; hence it is necessary to employ the opaque meal and opaque enema for radiographic investigation of these parts. Two important limitations are imposed by this method : (1) The lumen only of the viscera is visualized. (2) If the viscus contains any considerable quantity of the opaque substance, only that part of the lumen is visualized which can be seen in profile. Fortunately this latter difficulty can be largely overcome by the adoption of suitable technique.

Pure barium sulphate has now largely superseded the bismuth salts which were formerly employed as an opaque medium ; it is much less costly than bismuth carbonate, and equally efficacious. It is essential, however, that the barium sulphate be prepared specially for internal administration, as the commercial salt contains impurities which are of a highly poisonous nature. The exact composition of the opaque meal is largely a matter of individual preference, but the following conditions should be fulfilled :

(1) The meal should be quite fluid ; this enables the opaque material to enter small irregularities of the visceral lumen. (A bolus of greater consistency is sometimes necessary for examination of the œsophagus, as will be described later.)

(2) The barium must be held in suspension in the fluid medium.

(3) The meal must as far as possible be rendered palatable by addition of some flavouring material.

(4) The total quantity given should approximate to a pint in most cases, and this should contain 6–8 ounces by weight of the barium salt. Examinations of the œsophagus, however, require only a small quantity of opaque fluid.

The opaque enema must conform to conditions (1) and (2), the flavouring material being omitted.

Considerable divergence of opinion exists as to the relative value of the fluorescent screen and the skiagram in examinations of the

alimentary tract. The author considers that both media should be utilized, but in the majority of cases he has much greater confidence in the skiagram than in the screen image.

As regards the diagnosis of *organic* lesions by the opaque meal and enema, two quite dissimilar methods are available. In the older, indirect method observations are recorded of functional abnormalities, and these are correlated with clinical and laboratory findings to form symptom-complexes, each representing a pathological condition. Exponents of the direct method, on the other hand, strive to demonstrate the actual deformity in outline produced by an organic lesion, and are largely uninfluenced, as regards diagnosis of such a lesion, by abnormalities of function. A positive finding by this method is of very great value, in many cases, indeed, being absolutely conclusive, but much less importance can be attached to a negative result.

In the following descriptions the direct method is adhered to for the diagnosis of organic disease.

The Pharynx and Œsophagus

Method of examination.—The investigation of the pharynx and œsophagus must be conducted with the patient in the standing or sitting position. A preliminary screen examination is first made of the whole thorax in the postero-anterior plane, and any abnormal opacity in the lungs, superior or middle mediastina is noted. The patient is then rotated towards his left (the right shoulder thus coming forwards) through an angle of about 45 degrees. This rotation should be controlled by observation on the fluorescent screen, and arrested when the translucent strip which appears between the spine and the cardiac opacity reaches its maximum width. In the plane of this translucent area are the contents of the posterior mediastinum, and the patient is now in the " first oblique " or " right anterior oblique " position, which affords a view of most of the œsophagus unobstructed by the shadows of the spine or heart and great vessels. An unobstructed view of the lower extremity of the œsophagus is best obtained by rotating the patient towards his right, into the " second oblique " or " left anterior oblique " position, but in practice it is not often found necessary to do this.

A few ounces of thin barium emulsion are then swallowed by the patient, and followed on the fluorescent screen from the mouth to the stomach. Should no abnormality be seen, a mouthful of thick barium paste, or finely-crumbled bread soaked in the thin emulsion, is swallowed and traced downwards into the stomach. In no circumstances should the semi-solid bolus be administered in the first instance : impaction of such a bolus on a tight, high stricture entails profound and totally unnecessary distress, and may be followed by disastrous consequences :

and this warning applies with even greater force to the earlier practice, now almost entirely abandoned, of administering capsules or cachets containing the opaque salt.

Normal appearances.—Opaque fluid, when swallowed, is propelled with great rapidity through the pharynx, so that it is difficult to obtain any clear conception of the method of passage. Once in the œsophagus, the rate of transit, though still rapid, is considerably decreased. The fluid is seen to pass quickly down in a continuous stream to the cardiac orifice. No evidence of active peristalsis is obtained, nor is there any segmentation of the stream. The lumen of the œsophagus is equal throughout, except opposite the transverse arch of the aorta, this structure producing a smooth, curved, shallow depression in the anterior aspect of the gullet. No perceptible interval elapses between the arrival of the fluid at the cardiac orifice and the relaxation of the sphincter, but since the sphincter does not relax to more than about one-fourth of the œsophageal diameter the fluid tends to collect temporarily in a column in the lower end of the œsophagus. This column does not exceed 3–4 inches in height, and, unless more fluid is continually swallowed, disappears into the stomach in a few seconds. The cardiac sphincter remains relaxed for the whole of this time.

An opaque bolus of barium paste or bread soaked in barium emulsion passes through the pharynx almost as quickly as does the opaque drink. It can be seen that each portion swallowed is formed into an oval mass and undergoes no segmentation. The passage of such a bolus through the œsophagus is comparatively slow and may be accompanied by a certain amount of segmentation, and slight peristalsis, producing rapidly progressing wave-like undulations, is sometimes seen. The bolus not uncommonly shows a transient arrest of movement opposite the aortic arch. Antiperistalsis does not occur in the normal œsophagus during deglutition. The more solid bolus passes through the cardiac orifice more slowly than fluid, but there is no delay in the initial relaxation.

In **dysphagia of nervous origin** the disability is seen to affect the passage of the bolus from the mouth into the pharynx. Once the bolus has entered the pharynx the act of deglutition proceeds normally.

Pharyngeal and œsophageal pouches.—Two forms of pouch or diverticulum are described—traction diverticulum of the œsophagus, and pressure diverticulum of the pharynx. *Traction diverticulum* is exceedingly rare, and results from contraction of adhesions formed between the œsophagus and adjacent structures. The diverticula thus formed are small (less than an inch in length) and cone-shaped, the base of the cone opening into the lumen of the gullet,

Opaque material entering these will produce triangular shadows projecting from the normal contour of the lumen.

The pharyngeal pouch is of much greater importance, although it is rather rare. The opening of the pouch is usually situated posteriorly in the mid-line of the pharynx immediately above the pharyngo-œsophageal junction. As the pouch increases in size its lower part may be seen to project slightly to right or left, but very large pouches are generally median in position.

On fluoroscopic examination during deglutition the opaque fluid is seen to collect in a rounded sac, and to pass down the œsophagus *in front of* this sac when the latter is partly or completely filled. The upper end of the œsophagus is then seen to be displaced forwards. The position of the pouch varies with its size : small pouches are confined to the lower cervical region, but if a large pouch be present the lower pole, forming a shallow concavity with a broad horizontal fluid level, occupies the thorax behind the superior mediastinum. These large pouches do not *fill* with opaque fluid ; they nearly always contain a considerable quantity of mucus and food, through which the heavier barium emulsion sinks to outline the lower pole of the diverticulum. (Plate 68, Fig. 1.)

Pharyngeal pouches should present little if any difficulty in diagnosis. A superficial resemblance to stricture of the œsophagus may exist, but demonstration of the œsophagus passing down in front of the retained collection effectually excludes such a lesion. Moreover, dilatation of the œsophagus does not occur to any appreciable extent above strictures in the cervical region ; while an obstruction in the upper part of the thoracic œsophagus is never responsible for the enormous dilatation which would be indicated by the lower pole of a pouch extending into the thorax.

Pressure of a large pouch on the œsophagus may produce a transient delay in the passage through this structure.

Obstruction of the œsophagus.—Obstruction may result from—

(1) Spasm.
(2) Organic strictures.
(3) Pressure from without.
(4) Impaction of a foreign body.

(1) Œsophagectasia is a form of chronic œsophageal obstruction resulting from spasm of the circular muscle at, or just above, the cardiac orifice. (Hurst considers the condition to be due, not to spasm, but to failure of inhibition.) On fluoroscopy during deglutition the whole œsophagus is seen to be dilated, often to an enormous extent. A horizontal fluid level can generally be seen 4–6 inches above the cardiac orifice, and through this fluid the barium emulsion rapidly

Fig. 1.—Œsophageal pouch.

Fig. 2.—Œsophagectasia.

Fig. 3.—Multiple congenital strictures of œsophagus.

Fig. 4.—Carcinomatous stricture of œsophagi

PLATE 68.

sinks. The lower extremity of the œsophagus is thus demonstrated, and presents a conical formation with perfectly smooth outlines. When a certain quantity of fluid has collected in the dilated gullet, a thin stream is seen passing onwards from the apex of the cone to enter the stomach. The enormous dilatation and cone-shaped extremity of the œsophagus are strongly suggestive of œsophagectasia, but these appearances are sometimes exactly simulated by an organic obstruction at the cardiac orifice. The diagnosis can be made with certainty by observing on the screen the passage of a long rubber tube filled with mercury ; the weight of this is sufficient to overcome the spasmodic obstruction, so that the tube passes readily into the stomach. An organic constriction remains impermeable to the tube. (Plate 68, Fig. 2.)

Transient spasmodic obstruction is said to occur sometimes in alcoholics, but the author has not seen this condition.

(2) **Organic strictures.** — *Congenital strictures* of the œsophagus are very rare. They usually occur in the middle or lower third of the gullet. Considerable dilatation is seen above the constriction, and the lower extremity of the dilated portion shows a smooth rounded outline. Antiperistalsis may be observed, as in all organic obstructions. A thin but regular stream passes through the stricture, which is usually of annular form and quite localized. (Plate 68, Fig. 3.)

Acquired organic strictures may be fibrous or neoplastic. Fibrous strictures are usually short and regular, and may be multiple. Considerable dilatation occurs above the obstruction, but the lower dilated extremity shows a smooth regular outline. Vigorous peristalsis and antiperistalsis may be seen.

The vast majority of organic strictures are due to neoplasm (carcinoma). These growths may arise in any part of the œsophagus, but the most common sites are opposite the 7th–8th dorsal vertebræ, and just above the cardiac orifice. Neoplasm of the pharynx and upper end of the œsophagus is productive of so much distress on deglutition that no satisfactory radiographic demonstration is possible.

· The characteristic features of all demonstrable neoplastic strictures are—(a) the long, tortuous nature of the constriction, and (b) filling defects in the lumen of the œsophagus immediately above the actual stricture. Filling-defects are due to encroachment on the lumen of the œsophagus by extension upwards of the growth above the level of the tight constriction. They are recognized as irregular indentations of the lumen as opposed to the smooth rounded outline seen in fibrous or spasmodic strictures. (Plate 68, Fig. 4.)

Vigorous peristalsis and antiperistalsis are always seen in these cases, being more marked the higher the lesion in the thorax ; conversely, dilatation is slight above a high obstruction, but usually

considerable when the growth is situated towards the cardiac orifice ; as noted above, it may be impossible to distinguish a neoplastic obstruction in the latter situation from œsophagectasia without the passage of the mercury-filled tube.

(3) Pressure on the outer aspect of the œsophagus may produce some degree of obstruction. The commonest lesions to have this effect are large aortic aneurysms and malignant growths of the mediastinum.

The diagnosis depends on recognition of the primary lesion, the preliminary screen examination being directed to this end. The pressure of an aneurysm rarely causes any very marked degree of œsophageal obstruction, but mediastinal neoplasms sometimes surround and later invade the gullet and produce extensive constriction.

The transient delay which may result from pressure of a large pharyngeal pouch has already been noted.

(4) Impaction of foreign bodies.—Large bodies, such as coins, are generally arrested either at the upper or the lower extremity of the œsophagus ; irregular bodies, such as small artificial dentures, or fragments of bone, may become impacted at any level. Foreign bodies opaque to X-radiation can be recognized on the fluorescent screen if of large size, but a skiagram may be necessary for demonstration of a small opacity. The location of an opacity in the œsophagus can be confirmed by observing the passage of a mouthful of barium emulsion, which surrounds and possibly obscures the impacted object.

The presence of foreign bodies non-opaque to X-radiation can also frequently be diagnosed by observation of deglutition. The stream of barium emulsion may be temporarily arrested at the level of impaction, or may be divided into two or more smaller streams.

The actual degree of obstruction to fluid produced by impacted bodies is not generally very great.

The Stomach and Duodenum

Method of examination.—The patient attends for examination in the morning, having abstained from breakfast. A small cup of tea and one slice of toast can be taken, however, not less than two hours before the appointment ; preliminary gastric lavage may be advisable in cases of suspected pyloric obstruction, but otherwise is best omitted.

The taking of aperient medicine is of little moment if the examination is to be confined to the stomach and duodenum, but if it is intended to trace the meal through the lower portions of the alimentary canal no aperient medicine should be allowed for thirty-six hours prior to the first appointment.

The patient is placed in the upright screening stand, and a brief

fluoroscopic examination is made of the thorax, with a view to noting abnormal opacities and confirming the type of habitus. He is then rotated into the first oblique position and instructed to drink the opaque meal, consisting of a pint of barium emulsion. The first few mouthfuls are followed through the œsophagus, and the patient is then rotated back into the frontal position for observation on the filling of the stomach. After a few ounces have entered this viscus the examination is discontinued while the patient finishes the meal. Fluoroscopy in the upright position is then resumed, and the shape, tone, position and motility of the stomach are noted; deformities of outline are sought, the patient being slowly rotated first to his left, then to his right, so as to bring all parts of the visceral lumen into profile. Skiagrams are obtained in the postero-anterior plane, and also in any oblique plane in which fluoroscopy appears to show an abnormality of outline. The duodenum is next examined for shape, size, deformities, displacements, and rate of transit of the opaque contents. Skiagrams of the duodenum are then obtained, and are preferably of serial form, i.e. a small aperture in a lead-covered screen is adjusted over the duodenum, and a series of exposures made on 12 × 10 films; usually six small skiagrams can be obtained on a film of this size. The interval between the exposures should not be according to any rule, but should be regulated by the rapidity with which the meal is leaving the stomach, a slow rate of exit demanding a comparatively long interval between exposures, and vice versa.

Serial skiagrams can also be obtained of any particular portion of the stomach the screen image of which appears to render this procedure desirable.

The patient is then placed prone on the X-ray couch. In this position the cardiac end of the stomach is filled with the meal, and observations of motility and of the duodenum are often facilitated. The examination with the screen is again followed by the taking of skiagrams.

Palpation of the abdomen with the protected hand or a large wooden spoon during screen examination is often of considerable value; an attempt should be made, by pressing the tips of the fingers vigorously into the abdominal wall, to empty successive portions of the stomach. In this way it is often possible to determine areas of rigidity in the visceral walls, and also to visualize the gastric mucosa outlined with residual emulsion. This procedure is, however, of very little value in hypersthenic subjects, in whom much of the stomach is out of effective reach, or in those of a less vigorous habitus, whose anterior abdominal muscles are maintained in a state of voluntary or involuntary rigidity.

The patient is seen again four hours later, no food being allowed in the interval. This usually suffices for examination of the stomach and duodenum, but further visits are necessary eight, twenty-four and sometimes forty-eight hours after the meal if the emulsion is to be followed through the lower part of the alimentary tract.

An alternative method, which is of great value in institution practice, consists in giving an opaque meal six hours before the patient attends for examination. The preliminary investigation is then directed towards the parts filled by this first meal and determining the presence of any opaque residue in the stomach. A second meal is then given, and the examination of the stomach and duodenum by means of this second meal is conducted as described above.

The first meal is known as the " six-hour " or " motor " meal, since it is used primarily to indicate the rate of passage through the upper part of the gastro-intestinal tract. Some workers advocate a motor meal of different composition from that used for the more detailed examination ; there does not appear to be any advantage, however, in thus complicating the details of administration ; the same form of barium emulsion serves both purposes equally well.

Normal appearances of the stomach. Filling of the stomach.—Screen examination of the abdomen before any of the meal is swallowed shows a rounded or oval translucent area immediately below, and outlining the under-surface of, the left leaf of the diaphragm. This area, the *Magenblase*, represents the collection of gas normally present in the upper pole of the stomach above the level of the cardiac orifice. The quantity of gas present varies considerably in the same individual, and is fairly constantly of larger amount in some subjects than in others. A straight horizontal lower border to the translucent area indicates the presence of fluid in the stomach.

The first mouthfuls of opaque fluid are seen to collect temporarily immediately below the level of the cardiac orifice, forming a triangular opacity with the apex pointing downwards.

After an interval of a few seconds the lumen of the stomach is canaliculized by the rapid passage downwards of opaque material, and the triangular opacity at the cardia is thus replaced by a narrow shadow of uniform width extending from the pyloric to the cardiac orifices. As the remainder of the meal is swallowed it will be found that accommodation is provided by a fairly general expansion of the visceral lumen ; in other words, the original uniform opaque column undergoes a progressive increase in girth rather than any alteration in shape, a phenomenon which is dependent on normal tone of the gastric musculature. This statement requires modification in certain types of habitus, as will be noted later.

Generally speaking, the outlines of the gastric lumen are perfectly smooth and regular, though undergoing constant variations in form owing to successive waves of peristaltic contraction.

It is not unusual, however, to see small, sharply defined and somewhat angular indentations in the contour, especially of the greater curvature. These indentations are frequently multiple, and remain constant over a long period ; they are due to prominent gastric rugæ seen in transverse section as projections into the lumen. Occasionally small gas-bubbles retained in the fold of the mucosa are productive of somewhat similar appearances.

In view of the fact that the heavy barium meal is sometimes stated to produce an abnormally low position of the stomach, it is of interest to note that the level of the viscus undergoes but little alteration between canaliculization of the lumen by the first mouthfuls of fluid and ingestion of the whole meal. It appears certain, therefore, that the position of the stomach seen immediately after taking the barium emulsion is a true indication of the level under normal conditions. It is possible that, in the later stages of emptying, the heavy residue may induce a lower level than would obtain with ordinary diet. Similarly, it can be shown that the tone of the stomach is not adversely affected, at any rate in the earlier stages of emptying, by the unusual weight of the meal.

Shape, tone, and position of the stomach. — As already pointed out, the tone and position of the normal stomach show profound variations in accordance with the habitus of the patient, and minor variations in different individuals of the same habitus, and even in the same individual on different occasions. The same statements apply with equal force to the shape of the stomach.

No description of normality is feasible, therefore, unless based on the habitus of the subject, and even then considerable latitude must be allowed for individual variations.

In general terms the **shape** of the normal stomach will be found to conform to one of two types—(1) the transverse type, and (2) the fish-hook or vertical type.

(1) The transverse type is less common, and is seen in the majority of hypersthenic and in a good many sthenic subjects. It closely resembles the conception of gastric form current in the older anatomical textbooks. The long axis is directed from the cardia to the right and slightly downwards, the pyloric orifice forming the lowest point of the gastric outline in well-marked examples of the type.

The *tone* of this form of stomach is exaggerated (hypertonus), and as a result the lumen of the viscus shows progressive diminution in width from the cardiac to the pyloric orifice. As regards *position,*

the transverse stomach is usually confined entirely to the supra-umbilical region of the abdomen. In the upright postero-anterior position the margins of the gastric opacity represent the lesser and greater curvatures, but in the horizontal-prone position the upper and lower profiles are formed by some part of the anterior and posterior surfaces respectively.

(2) The fish-hook or vertical type of stomach is far more common than the transverse, occurring in many sthenic and in all hyposthenic and asthenic subjects.

The lesser curvature, as seen in the postero-anterior plane, descends vertically from the cardiac orifice, or with a slight inclination to the right. At a point some three-fourths or four-fifths of the distance down towards the pylorus the lesser curvature describes a sharp curve to the right and then upwards to the pylorus. Sometimes the fish-hook outline is even more closely simulated by final inclination of the pyloric antrum to the left.

The *tone* of the fish-hook stomach in sthenic and many hyposthenic subjects is such that the lumen of the vertical limb is maintained at a uniform width throughout its whole extent (orthotonus). In asthenic and some hyposthenic subjects the gastric tone is insufficient to maintain the long vertical column of fluid in a uniform cylinder; the walls of the upper part of the vertical limb tend to approximate more or less closely to one another, the maximum approximation occurring at a point some little distance below the cardiac orifice; and the major portion of the meal occupies the more dependent part of the viscus. In these circumstances the upper fourth of the vertical limb is usually devoid of opaque contents, and the lower portion presents a column which increases in width from above downwards. Ingestion of more fluid in such a stomach results merely in further expansion of the lumen already occupied.

The level of the lowest point on the lesser curvature in the upright posture forms the criterion for estimating the *position* of the fish-hook stomach. In sthenic subjects this is generally seen $\frac{1}{2}$–$1\frac{1}{2}$ inches above the highest point of the iliac crests; in hyposthenics it is about the level of the iliac crests, while in asthenics it is usually slightly below this level. The greater curvature must not be considered in the estimation of position, since the level to which this descends is partly dependent on gastric tone.

Abnormalities of gastric tone and position can only be justly appraised when due consideration is accorded to the habitus of the patient.

The terms used to describe the tone of the stomach can be defined as follows :

Orthotonus indicates that the gastric contents are supported as a

column of uniform width from the cardiac orifice to the lowest level of the lesser curvature.

Hypertonus indicates that the column is of greater width in its upper part.

Hypotonus indicates that the column increases in width from above downwards, the upper portion of the lumen frequently remaining empty.

Atonus indicates that the upper level of the gastric contents is not supported above the lowest point of the lesser curvature. In this condition a single horizontal fluid level is seen, the outline of the gastric contents forming a segment of a circle. Observation of the filling of the stomach enables the atonic stomach to be distinguished from one which contains a large quantity of non-opaque fluid, the final disposition of the opaque meal in the lower pole of the viscus being similar in both cases.

If these definitions be adopted, *orthotonus* may be considered a normal appearance in all subjects, while *atonus* is invariably abnormal. *Hypertonus* is also a normal condition in hypersthenics and sthenics, but is definitely abnormal in the elongated fish-hook stomach of the hyposthenic or asthenic subject. *Hypotonus* must be regarded as normal in hyposthenics and asthenics, but as abnormal in hypersthenics and sthenics.

Local spasm of the gastric musculature will be described in con-nexion with the diagnosis of organic lesions.

The term *cascade stomach* has been applied to a peculiar pheno-menon thought to be produced by increased tone of the oblique muscle-fibres.

If such a stomach is observed during ingestion of the opaque meal it will be seen that the fluid collects at first in a wide cul-de-sac formed by a downward projection of the whole posterior surface of the stomach at the level of the cardiac orifice. When this cul-de-sac is filled the meal " spills over " its anterior border to canaliculize the remainder of the gastric lumen. The condition is best demonstrated by a lateral or oblique position of the patient.

The significance of this phenomenon is not known ; in the present state of knowledge it is not justifiable to regard the condition as abnormal.

Dilatation of the stomach is represented radiographically by atony, or the more severe forms of hypotonus.

Ptosis is indicated if the lowest point on the lesser curvature lies less than 1 inch above the level of the iliac crests in a hypersthenic subject, definitely below the level of the crests in sthenic or hyposthenic subjects, or more than $\frac{1}{2}$ inch below the crests in an asthenic subject.

The position of the stomach, however, shows considerable variations

in the same individual on different occasions, depending on the condition of the small and large intestine, and also on fatigue.

Motility of the stomach.—Peristalsis is normally observed almost immediately after the stomach is canaliculized by the opaque meal, and continues uninterruptedly until the stomach is empty. The contractions are seen to commence quite high up on the greater curvature, often not more than an inch below the level of the cardiac orifice. They appear in this situation as very shallow smooth depressions in the greater curvature only, no corresponding depression being seen in the lesser curve. Each depression moves downwards, becoming deeper and wider, and when about one-third of the way towards the pylorus a depression in the corresponding part of the lesser curvature can be discerned, indicating the formation of a continuous constriction-ring around the lumen. The movement of the peristaltic wave continues at a regular rate, and is accompanied by progressive increase in depth of indentation until, at a point usually about 1 inch from the pylorus, the lumen is completely obliterated. That portion of the stomach which lies between the pylorus and this complete constriction is known as the pyloric antrum, and it is obvious, therefore, that this term as used by the radiologist is represented by a variable segment of the stomach in different individuals, and is impossible of definition in anatomical terms.

The constriction-ring moves over the pyloric antrum until within about ½ inch of the sphincter, and then fades away. Relaxation of the sphincter may occur, usually about the time the complete ring is formed, with subsequent expulsion of the antral contents into the duodenum ; or the sphincter may remain closed, in which case the antral contents escape back through the ring in a fine, hardly perceptible stream. Sometimes the sphincter is seen to relax on the near approach of each constriction-ring, but frequently it remains closed to three or more consecutive waves. The time of initial relaxation after ingestion depends in the normal stomach largely on the *consistency* of the gastric contents ; relaxation should be observed within a minute of taking the fluid barium meal recommended for these investigations, and frequently occurs within a much shorter space of time. Expulsion of some of the gastric contents into the duodenum is followed by immediate closure of the pylorus, and this relaxation followed by immediate closure is known as the " pyloric reflex." Usually speaking, two or three peristaltic waves can be observed at the same time between the cardia and the pylorus, constituting an orderly and continuous progression.

In addition to peristalsis, small localized undulating contractions have been described in the stomach, and also movements of the gastric mucosa occurring independently of any demonstrable contractions

of the muscular walls ; the significance of these phenomena is unknown, but it is suggested that they play some part in promoting a uniform distribution of the gastric secretion throughout the ingesta.

The normal *emptying-time* of the stomach is subject to very wide variations in different individuals and in the same individual on different occasions, even when identical conditions obtain at each examination. The quantity, and to a much less degree the constitution, of the meal also affect the rate of emptying.

If a pint of barium emulsion is taken, the maximum normal time of emptying may be regarded as six hours (hence the significance of the six-hour motor meal), and the minimum time as three-quarters of an hour. Variations within these limits possess no significance whatsoever.

It is essential in estimating the emptying-time that no food be taken until the stomach is completely void of opaque material. Admixture of food with an opaque residue completely vitiates the value of any subsequent observations. Hence the true emptying-time can rarely be determined in cases of marked gastric delay, since it is not feasible to starve the patient until emptying is completed.

Abnormalities of peristalsis.—The motility of the stomach may be defective, exaggerated or disordered.

In **defective motility** the peristaltic waves are infrequent and shallow ; a single wave only may be seen at any one time ; or several waves may follow in normal sequence, with subsequent complete immobility of the gastric musculature. Sometimes many of the shallow indentations fade away before reaching the pyloric portion of the stomach, or an indentation may remain stationary for a considerable period and then progress, or disappear completely.

Exaggerated motility is shown by an increased depth of the indentations in the upper part of the stomach, increased rapidity of the progress of the waves, and the presence of four or five waves at one time between the cardiac and pyloric orifices. Exaggerated motility may persist until the stomach is emptied, or may be intermittent. A slight degree of exaggeration is quite common as a result of hunger.

No constant relationship obtains between tone and motility ; in fact a severe degree of hypotonus is often coexistent with normal or even exaggerated peristalsis.

Disordered motility, consisting of a complete or partial replacement of the normal sequence of peristalsis by the appearance of irregular, unequal and apparently purposeless muscular contractions, is rarely seen in the absence of organic disease. A less marked phenomenon, but one also indicative of an organic lesion, consists of a gap in the progress of peristalsis, each wave ceasing at a certain point in the

gastric outline, and reappearing nearer to the pylorus, the intervening portion of the viscus remaining quite immobile.

Antiperistalsis has been described in some organic lesions of the stomach, but must be exceedingly rare—if, in fact, it occurs at all, which is open to doubt.

The normal duodenum.—The opaque gastric contents expelled with each relaxation of the pyloric sphincter are retained for an appreciable period in the first part of the duodenum. The shadow produced by this collection is known as the " duodenal cap " ; it is somewhat cone-shaped but with a rounded apical surface, the flat base corresponding with the duodenal aspect of the pyloric sphincter. All the margins of the cap are perfectly smooth and regular in outline, whether seen in a postero-anterior or an oblique plane, and the opacity is uniformly dense. After an interval, usually of from two to six seconds, contraction of the first part of the duodenum produces rapid expulsion of the contents into the second or descending portion. Simultaneously the duodenal contents are segmented, so that they no longer appear as a uniform density but as one broken up into a number of opacities, which blend and redivide. The head of this irregular opaque column passes rapidly through the second part of the duodenum into the third or transverse portion. Here it is usually arrested for a moment, and slight regurgitation may occur ; the opaque contents then pass quickly onwards, are lost to sight for a brief interval behind the stomach, and then reappear at the duodeno-jejunal flexure, which by a little rotation of the patient can be made out just to the right of the lesser gastric curvature. There is no delay at this flexure, the duodenal contents passing uninterruptedly into the jejunum.

Relaxation of the pyloric sphincter does not occur until the contents of the first part of the duodenum have been partly or completely expelled into the second portion—i.e. the presence of the duodenal cap apparently inhibits such relaxation.

The duodenal cycle described above is constant in all normal adults, and in children after the first few months of infancy, but can be observed much more readily in the fish-hook than in the transverse type of stomach : in the latter the pyloric canal is directed somewhat backwards, and the first part of the duodenum, lying partly behind the shadow of the pyloric antrum, is often considerably obscured.

This fact, coupled with the bulk of the patient, renders examination of the duodenum in hypersthenic subjects a matter of considerable difficulty.

In hyposthenic and asthenic patients the pylorus lies at a much lower level, and the canal is directed almost vertically upwards, or upwards and slightly to right or left. Not only is examination thus

Fig. 1.—Diverticulum of stomach.

Fig. 2.—Congenital duodenal obstruction.

PLATE 69.

facilitated by freedom from overlapping shadows, but retention of the cap also commonly occupies a longer interval than in those of more robust physique.

The low position of the pylorus is necessarily associated with elongation of the first part of the duodenum, since the position of the second and third parts is fairly constant. The duodenal cap in these circumstances occupies only the proximal portion of the first part, and contraction forces the contents *upwards* to enter the second part.

Dilatation of the first part of the duodenum, with unduly prolonged retention of a large cap-formation, is not uncommonly seen in association with a markedly hypotonic stomach ; this appearance, although certainly abnormal, does not seem to possess any very definite clinical significance.

In young infants there appears to be no proper duodenal cap-formation, the duodenal contents being immediately segmented and passed onwards.

Congenital abnormalities of the stomach and duodenum. — Gastric diverticulum is seen as a perfectly smooth-walled, rounded shadow projecting from the normal contour of the stomach. The usual site for diverticulum is on the posterior wall of the stomach, near the lesser curvature, and slightly below the cardiac orifice. In adults, in whom the condition is usually first recognized, the diverticulum is generally the size of a cherry, or larger. Palpation during fluoroscopy elicits the fact that the diverticulum is slightly mobile (since the communication with the gastric lumen consists of a narrow neck), and is, moreover, " soft "—i.e. the contour of the diverticulum is dimpled by pressure of the palpating finger. This latter feature can only be elicited if the abdominal wall is thin and flaccid and the diverticulum does not lie under cover of the costal margin.

When the stomach has partly emptied, the orifice in the gastric mucosa communicating with the diverticulum can often be demonstrated as a ring-like shadow, $\frac{1}{4}$ inch or more in diameter, outlined against the gas in the cardiac end of the viscus.

The large size, smooth contour and rounded shape of a soft, mobile projection from the cardiac end of the stomach should suffice to establish a correct diagnosis of diverticulum. (Plate 69, Fig. 1.)

Acquired diverticulum of the stomach, resulting from the traction of a localized adhesion, is seen as a small conical projection of the contour, the free extremity forming the pointed apex, while the base is directly continuous, without any intervening constriction with the gastric lumen.

The size and shape of the projections vary with alterations in

posture as the tension on the causative adhesion is accentuated or relaxed.

Congenital diverticula of the duodenum are comparatively common, and are often multiple. They are usually connected with the outer or under aspect of the first portion or the inner aspect of the second portion, and not infrequently lie in the angle of junction between the two. They are seen as smooth-walled rounded shadows varying from the size of a pea to that of a cherry, and connected with the duodenal lumen by a constricted neck.

Occasionally patency of the papilla of Vater, with dilatation of the lower end of the common bile-duct, may result in the formation of an extraduodenal shadow rather closely simulating the appearances of a diverticulum. The position, direction, and more elongated shape of the opacity in the former case usually render possible a distinction between the two conditions. This distinction is, in point of fact, of considerable importance, for, while duodenal diverticula are devoid of any clinical significance, patency of the papilla of Vater is strongly suggestive of a lesion of the biliary tract.

Congenital hypertrophic pyloric stenosis presents features which differ in minor details only from those of acquired stenosis in its later stages, described below. The stomach is greatly enlarged, and is either hypotonic or atonic, while motility is alternately exaggerated and defective. The opaque fluid is observed passing into the duodenum in very small quantities only, and at infrequent intervals, if at all. Frequent vomiting usually renders it difficult to estimate the emptying-time of the stomach, but should the meal be retained a large gastric residue will be seen at the end of two hours. In this connexion it must be remembered that the normal infantile stomach is subject to much less variation in rate of emptying than that of an older subject, and that a meal of a quantity suitable to the age of the patient (i.e. 2–3 ounces) should have entirely left the stomach at the end of one and a half to two hours.

The chief difficulty in diagnosis consists in distinguishing an organic obstruction from a pyloric spasm. In the latter condition the spasm undergoes occasional relaxation, with subsequent rapid exit of gastric contents into the duodenum. This relaxation may not occur for some considerable time, and meanwhile most of the opaque meal may be vomited, so differential diagnosis is often exceedingly difficult. The difficulty is accentuated by the enfeebled state of the infant and the necessity for reducing all manipulations to a minimum.

As regards administration of the meal, this is best effected by passage of a stomach-tube and preliminary gastric lavage, after which 2–3 ounces of thin warm barium emulsion are poured down the tube,

which is then removed. The infants bear this procedure exceedingly well if protected from exposure to cold.

Congenital duodenal obstruction results from a developmental error whereby some part of the duodenum is compressed by a band, or kinked, the latter condition usually arising in imperfect rotations of the large gut. The radiographic appearances are similar to those of pyloric stenosis, except that the duodenum proximal to the obstruction is distended. (Plate 69, Fig. 2.)

Acquired organic lesions of the stomach and duodenum.—Diagnosis of organic lesions of the stomach and duodenum depends upon the demonstration of a *constant* deformity of the lumen of these viscera ; such deformity is frequently visualized on the fluorescent screen, but confirmation of the screen image should always be sought in the skiagram, upon which the ultimate radiographic diagnosis must be based. This dependence on the skiagram is rendered necessary (1) by the frequency with which errors arise in interpretation of the comparatively fleeting impression of the screen image, and (2) by the fact that very small lesions, readily recognized in the skiagram, may be quite invisible on the most careful fluoroscopy.

Screen examination is, however, an essential preliminary, since it often forms an invaluable guide to the best positions for the subsequent skiagrams.

It is impossible to lay down any rule as to the number of gastric or duodenal skiagrams required ; a single plate may establish a diagnosis of lesser-curvature ulcer beyond all reasonable doubt, while a series of twelve or more small pictures of the duodenal cap may leave the radiologist still undecided as to the presence or absence of a duodenal lesion—a state of affairs which indicates the necessity for further serial views of this part.

It must be emphasized that the constancy of deformity constitutes the foundation of this method of diagnosis ; in other words, the operator must endeavour to obtain a normal skiagram, thus disproving an organic cause for any supposed deformity previously observed.

It is frequently stated that points of maximum tenderness on palpation of the abdomen correspond with lesions of the underlying portions of the stomach and duodenum. The author is convinced that such statements are completely fallacious, and that the tenderness observed is referred tenderness of the abdominal parietes, the only exception being provided by the rare instances in which a lesion of the stomach or duodenum is directly adherent to the anterior parietal peritoneum, or connected to that membrane by adhesions which are rendered tense on palpation. Theoretically the suggestion that nonadherent lesions are tender on pressure cannot be supported, since, as is well known, the stomach and intestines are quite insensitive to

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tactile and thermal stimuli ; practically, the position of a visualized ulcer can often be shown to vary in relation to the abdominal wall on change of posture to the extent of two or more inches, whereas the point of maximum tenderness remains absolutely unchanged. It is desirable, therefore, that such terms as " tender duodenal cap " and " tender point on the lesser curvature of the stomach " should fall into disuse.

As described later, true visceral pain may be produced on direct palpation over a diseased appendix or an obstructed coil of bowel, by causing an increased tension within the affected structure, which, as Hurst* has shown, is the probable causation of visceral pain.

The deformity indicative of an intrinsic organic lesion of any part of the alimentary tract may consist in an addition to the normal outline of the lumen, or a defect in the lumen, the latter being produced by inflammatory or neoplastic thickening of the visceral wall.

Extrinsic organic lesions (e.g. involvement in adhesions) may produce similar deformities by pressure or traction on the viscus, but these deformities can usually be distinguished by their variation on changes of posture or on palpation.

Gastric ulcer.—The deformities seen in benign ulcer of the stomach are : (1) a niche, (2) an accessory pocket, (3) a filling-defect.

(1) The **niche deformity** (Haudek's niche) consists of a localized projection from the lumen of the stomach representing the crater filled with opaque material, and is characteristic of perforating ulcer. It is most commonly seen on the lesser curvature or adjacent portion of the posterior surface, in the latter case being visualized with the patient in an oblique position.

The outlines of the projection are generally smooth, and there is no constriction at the junction of the niche with the visceral lumen. Immediately above and below the projection may be seen a smooth rounded filling-defect which represents the inflammatory thickening around the ulcer. (Plate 70, Figs. 1, 2.) Irregularity of this filling-defect or of the niche itself should arouse the suspicion of malignancy. The size of the niche varies from the smallest projection which can be recognized with certainty, to a basal diameter of $\frac{3}{4}$ inch. Should the base be of larger size, malignancy must be suspected, even though the deformity presents no other feature suggestive of neoplasm. (Plate 71, Fig. 2.)

Failure to demonstrate a niche deformity may result from temporary filling of the crater with bloodclot or food residue, and it is always advisable, therefore, to confirm a negative finding by re-examination of the stomach on a later occasion.

Niche deformities on the lesser curvature are often accompanied

* " Sensibility of the Alimentary Tract," 1911.

Fig. 1.—Small gastric ulcer.

Fig. 2.—Large gastric ulcer, niche deformity, spasmodic incisura of greater curvature.

Fig. 3.—Gastric ulcer, accessory pocket. Note gas-bubble above barium.

Fig. 4.—Filling-defect in pyloric antrum, due to ulcer.

PLATE 70.

by a localized spasmodic contraction of the circular muscle-fibres, producing an incisura on the greater curvature. (Plate 70, Fig. 2.) This incisura may be shallow, or so deep that the lumen of the viscus is reduced to a diameter of $\frac{1}{4}$ inch in the region of the ulcer. The spasm, moreover, may involve the musculature over a considerable area below the level of the ulcer, so that an inch or more of the gastric lumen is greatly constricted. These spasmodic hour-glass deformities will receive further consideration in connexion with other spasmodic conditions of the stomach.

(2) The accessory pocket represents an extension of the ulcer into the extragastric tissues (penetrating ulcer). A large projection is seen, connected to the lumen of the stomach by a constricted neck. The projection is rounded in shape, though the outlines are often slightly irregular, and may be accompanied by spasmodic incisura of the greater curvature ; this is, however, less common than in niche deformities.

The accessory pocket frequently contains a bubble of gas, so that a horizontal fluid level is seen when the patient is upright, and the entire opaque contents of the pocket are often retained after the stomach is empty—a point of distinction from the niche.

An accessory pocket is always fixed in position, being quite unaffected either by changes of posture or by palpation. (Plate 70, Fig. 3.)

(3) The filling-defect of a benign ulcer consists of a slight, localized depression of the gastric outline. The margin is quite smooth and regular, and the defect is shallow. This deformity is produced by the inflammatory induration which occurs around the circumference of the ulcer ; it often forms the only recognizable abnormality in ulcers involving the anterior or posterior surfaces of the pyloric antrum, owing to the difficulty in seeing these parts in profile and thus visualizing the crater. (Plate 70, Fig. 4.) Ulcers of the body of the stomach may also present no deformity but a small filling-defect, should the crater be temporarily filled with bloodclot or food residue ; in these circumstances, since the crater if filled can be visualized, a second examination should be made on a later occasion.

When an ulcer is situated very close to the pylorus, the induration of the lesion may produce a defect in, or distortion of, the pyloric canal as well as the antrum—a condition indicative of pyloric stenosis.

Small ulcers may heal without leaving any deformity of gastric outline demonstrable on X-ray examination ; or the stomach may present a deformity as a result of scar contraction. In the case of lesser-curvature ulcers this scar contraction tends to produce an organic incisura of varying depth and extent (the organic, or true, hour-glass stomach described below). Scarring of ulcers in the immediate

vicinity of the pylorus results in pyloric stenosis, a condition which requires more detailed consideration.

Benign pyloric stenosis results from an ulcer immediately on the gastric or the duodenal side of the pyloric sphincter. Only one radiographic sign is of absolute diagnostic value in this condition—the demonstration of a constantly deformed pyloric canal. Functional abnormalities of the stomach are often of confirmatory value, but reliance on these indirect manifestations alone provides a frequent source of error, since both in their presence and absence these signs may be completely misleading.

Typically the stomach of early pyloric stenosis shows exaggerated peristalsis and some degree of hypertonus. The meal leaves rapidly through a pyloric canal which shows comparatively little deformity, and the stomach is empty at the sixth hour—i.e. the slight degree of obstruction is entirely compensated by the hypermotility.

At a slightly later stage, owing to commencing exhaustion of the gastric musculature, periods of inactivity alternate with periods of hypermotility; and even during the active phase the meal leaves slowly through a canal showing considerable distortion and constriction. The tone of the stomach is definitely defective, and a six-hour residue, indicating delayed emptying, is seen.

In the late stages of pyloric stenosis the stomach is atonic and is capable of containing a large quantity of fluid. The pyloric portion of the lumen shows a characteristic dilatation outwards to the right, so that the pyloric canal appears displaced to the left in relation to the antrum, this deformity constituting the " prognathous antrum." The canal itself is visualized only by means of an exceedingly thin irregular stream of barium which occasionally passes into the duodenum.

Peristalsis is often absent over long periods, and when observed occurs as a greatly exaggerated wave, either isolated or followed by a short succession of similar waves. The dilated right side of the pyloric antrum often shows shallow, irregular contractions, which appear quite purposeless in character.

Nearly all the meal will be found remaining in the stomach at the sixth hour; and if the examinations are continued a gastric residue may be seen at the forty-eighth hour or later, but, as previously pointed out, these later observations do not form a true criterion of emptying-time owing to the mixture of subsequent ingesta with the opaque residue.

In early cases it is possible, as a rule, to recognize the situation of the ulcer responsible for the stenosis, especially if ulceration is still active. In later stages, however, it is generally quite impossible to decide whether the original lesion was gastric or duodenal. It should

Fig. 1.—Organic hour-glass deformity.

Fig. 2.—Carcinomatous ulcer of stomach.

Fig. 3.—Small annular pyloric carcinoma.

Fig. 4.—Carcinoma of body of stomach.

PLATE 71.

be noted that early pyloric stenosis presents one of the most difficult problems of diagnosis with which the radiologist is faced.

In well-established cases of obstruction another difficulty arises—that of distinguishing between a stenosis produced by scarring of an ulcer, and one due to an annular pyloric neoplasm. The abnormalities of tone, peristalsis, emptying-time, etc., described above are common to both lesions, since they merely represent the reaction of the gastric musculature to a progressive obstruction. In cases of pyloric neoplasm, however, the annular filling-defect produces an apparent elongation of the pyloric canal, and this long, narrow, and somewhat tortuous channel remains permanently canaliculized—i.e. the pyloric reflex is lost. The extensive filling-defect and the loss of the pyloric reflex should suffice to establish a diagnosis of neoplasm.

In advanced cases of carcinoma the channel through the growth may not be canaliculized while the patient is under observation, and a differential diagnosis between benign and malignant stenosis is then impossible.

Spasmodic contractions of the gastric musculature are responsible for the chief difficulty in diagnosis of organic lesions of the stomach. The spasm may be quite localized, resulting in a linear incisura of the greater curvature, or extensive, as in widespread contractions of the circular fibres whereby the stomach is divided into two sacs with an intervening long narrow channel.

In another form of spasticity the whole pyloric end of the stomach appears as a contracted spigot-shaped tube, devoid of peristaltic undulations. In these cases the pyloric reflex is frequently lost, the sphincter remaining patent and the meal leaving in a continuous stream.

Spasmodic deformities may be caused by an intrinsic organic lesion of the stomach, or may be observed in association with extra-gastric disease.

The spasmodic hour-glass stomach, represented either by a localized incisura or an extensive contraction of the lumen, is most commonly seen in connexion with perforating ulcers of the lesser curvature. This type of spasm may also occur in duodenal ulcer and appendicular lesions, and may in fact be seen in association with any intra-abdominal disease. It is not uncommon, also, to observe a spasmodic incisura of the greater curvature in sufferers from pulmonary tuberculosis. The spastic pyloric antrum is sometimes associated with an ulcer of this part of the stomach, but is far more commonly indicative of extra-gastric disease, especially lesions of the biliary tract.

These spasmodic deformities of the stomach give rise to two difficulties: (1) They may simulate an organic deformity; (2) they may conceal an organic lesion. Every effort must be made, therefore,

to obtain relaxation of spasm in all cases where a deformity might conceivably be of this nature. Not infrequently, spasmodic contractions are seen to undergo partial or complete relaxation during screen examination, and this relaxation may sometimes be induced by vigorous massage of the abdomen. Should this method fail, belladonna should be administered in three- or four-hourly doses until physiological effects are noted (i.e. dilatation of the pupils and dryness of the mouth), and further examination of the stomach should then be made.

Administration of belladonna is useless unless pushed to physiological effect, but if adequate dosage is insisted upon this drug produces relaxation of nearly all spasmodic deformities of the stomach which are not associated with an intragastric lesion. Hence persistence of the spasm in these circumstances is strongly indicative of organic disease of the stomach ; while complete relaxation, and subsequent failure to demonstrate an ulcer, suggest the presence of some extragastric lesion.

Spasm of the pyloric sphincter itself is sometimes seen in cases of ulcer of the immediately adjacent antrum, but is far more commonly noted in the absence of any organic gastric lesion, and probably bears a causal relationship to certain functional dyspepsias. It is rarely so persistent in the adult as to produce a definite gastric delay, but a good deal of perseverance may be needed for demonstration of the duodenum. (*See also* under Congenital Hypertrophic Stenosis, p. 176.)

Hour-glass contraction of the stomach.—As stated above, hour-glass deformities may be either spasmodic or organic ; in some cases superadded spasm accentuates a deformity which possesses an organic basis. In both spasmodic and organic forms the abnormality may consist of a simple localized incisura or a contraction involving one, two, or more inches of the gastric lumen. It is important to note that the margins of the upper and lower sacs are quite smooth and regular except for the possible presence of the niche or accessory pocket of an ulcer ; and that the contraction involves the greater curvature only. An irregular funnel-shaped contraction affecting both curvatures is indicative of neoplasm.

It is sometimes suggested that organic hour-glass deformities are characterized by a downward projection of the upper sac below the evel of communication with the constricted channel (Plate 71, Fig. 1.) This feature, if well marked, is certainly indicative of an organic contracture ; in the majority of cases, however, it is practically impossible to distinguish spasmodic from organic hour-glass deformities unless relaxation is in the former instance obtainable.

Tuberculosis of the stomach results in large irregular filling-defects of the body of the viscus, usually more apparent in

the region of the greater than the lesser curvature. Peristalsis is interrupted by these defects. The appearances bear a strong resemblance to those of malignant neoplasm, and a differential diagnosis is sometimes impossible. In tuberculosis, however, it is usual to find multiple defects separated by areas less deformed or free from deformity ; while in neoplasm the deformity, though often very extensive, is obviously produced by a single lesion.

Syphilis of the stomach.—While some authorities hold that syphilitic affections of the stomach are not uncommon, others deny that demonstrable gastric lesions occur in this disease. The author has not encountered any radiographic manifestations of proved gastric syphilis, while most of the skiagrams reproduced by others as representing the condition are identical with those of scirrhus carcinoma—an opinion which does not seem to be disproved by the subsequent history of the recorded cases. At the present time, therefore, a radiographic diagnosis of gastric syphilis is not justifiable.

Adhesions and mesenteric contractions.—Perigastric adhesions produce irregular deformities either by traction or by pressure. The characteristic feature of such deformities consists in their variability on change of posture and in response to different degrees of visceral distension.

Contraction of the gastro-hepatic omentum, however, usually resulting from healing of a lesser-curvature ulcer, produces an approximation of the pylorus to some part of the lesser curvature—i.e. the stomach assumes an exaggerated fish-hook shape. This deformity is not affected by changes of posture or by palpation, and is often associated with some contraction of the gastric lumen as a result of scar-tissue formation.

Pressure on the outer surface of the stomach by extragastric tumours, distended bowel, etc., produces a deformity in gastric outline which varies with changes of posture and is not associated with any interruption in peristalsis, observation of these two features affording conclusive proof of the causation of the defect, a possible exception being allowed only for some forms of the very rare benign tumours.

A rounded pressure-defect in the upper aspect of the pyloric antrum is sometimes produced by pressure of a distended gall-bladder, and will receive further mention in a later chapter (p. 211).

Neoplasms of the stomach.—Benign tumours of the stomach are exceedingly rare. Adenomas, myomas, and fibromas form the majority of reported cases. A benign tumour results in a more or less extensive, constant filling-defect if it projects into the lumen, and is then rarely distinguishable radiographically from a malignant growth ; should the benign tumour project externally,

the stomach shows displacement and deformity varying to a slight extent on change of posture, and the appearances then simulate those of pressure by an extragastric tumour.

Multiple polypoid growths of the mucosa can sometimes be distinguished with a fair degree of confidence owing to the extremely widespread and irregular nature of the filling-defects produced.

Malignant tumours of the stomach are, in the vast majority of cases, carcinomatous in nature.

Four distinct types of gastric carcinoma can be recognized on X-ray examination :

    (1) Carcinomatous ulcer.
    (2) Annular pyloric growths.
    (3) Growths affecting chiefly the region of the greater curvature.
    (4) Diffuse scirrhus carcinoma.

In addition to these common forms the irregular, constant filling-defect characteristic of malignant neoplasm may be observed in any part of the stomach.

(1) Carcinomatous ulcers, as distinct from excavations occurring in a large tumour mass, are quite rare. They may present the appearance of a niche distinguished only from that of a simple ulcer by its large size. A niche with a basal diameter of more than ¾ inch must be regarded with grave suspicion. More commonly, however, the carcinomatous ulcer presents irregularity in the outline of the niche, and small irregular filling-defects in the immediately adjacent gastric lumen. Irregularity of filling-defects, however small these may be, is always suggestive of malignancy. (Plate 71, Fig. 2.)

(2) Annular pyloric carcinoma is one of the commonest types of gastric cancer. The growth encircles the pyloric sphincter and adjacent antrum, producing, by reason of the antral filling-defect, an apparent elongation of the pyloric canal. (Plate 71, Fig. 3.) The infiltration of the sphincter renders closure of the pylorus impossible, so that the narrow channel through the growth remains unvarying in diameter. This persistent and unaltering gaping of the pylorus is seen in all neoplasms which involve the pyloric region of the stomach, and only ceases to be demonstrated when the central channel is almost obliterated by the growth.

The description of functional disturbances in benign pyloric stenosis holds equally good for obstruction due to pyloric neoplasm, with the proviso that since the neoplastic obstruction progresses more quickly, so the phases of functional derangement follow one another with greater rapidity.

Annular pyloric neoplasms are for a considerable time comparatively regular in shape, and hence the filling-defect shows a

smoothness of outline not seen in other forms of malignant growth. Eventually, however, ulceration of the mucosa and excavation of the underlying tumour provide the filling-defect with a typically ragged contour.

(3) Carcinoma extending along the greater curvature and adjacent surfaces, generally in the pyloric portion of the stomach, occurs with a frequency about equal to that of the annular pyloric growth. By the time this type of neoplasm is first seen there is usually an extensive filling-defect in the lower part of the pyloric antrum and contiguous portion of the body of the stomach. This defect is irregular and ill defined, owing to the uneven intrusion of the neoplasm into that portion of the lumen which still remains. Peristalsis is completely absent over the affected area, and palpation effects no alteration in the appearance of the defect. The pyloric sphincter is generally involved, and is then rigidly gaping. Pyloric obstruction is not a prominent feature until the disease is well advanced. (Plate 71, Fig. 4.)

(4) Scirrhus carcinoma produces the widespread infiltration known as "leather-bottle stomach." The radiographic appearances are very striking : the opaque emulsion runs straight through a narrow, tortuous, and completely immobile channel, which represents the lumen of the stomach, into the duodenum, the pylorus being widely gaping and sharing in the general rigidity of the viscus. It is difficult to obtain a satisfactory skiagram of the condition except while the patient is actually drinking the barium emulsion, since no appreciable retention of contents takes place in the stomach. (Plate 72, Fig. 1.)

It will be gathered from the above description of the more common appearances of gastric neoplasm that radiographic diagnosis is based on two characteristic features—the presence of a constant, unchanging, and usually irregular filling-defect in the lumen of the stomach, and the complete interruption of peristalsis over the affected portion of the visceral outline.

Sarcoma of the stomach is very rare ; the radiographic appearances are identical with those of carcinoma, no distinction between the two types of neoplasm being possible.

Foreign bodies in the stomach.—The position of an opaque foreign body seen in the upper abdomen can be accurately located by making a fluoroscopic examination while the patient swallows some barium emulsion. If the foreign body is in the stomach it is, of course, immediately overshadowed, and probably obscured, by the opacity of the fluid.

Trichobezoar (hair-ball), though rare, can usually be recognized on administration of an opaque meal. The stomach is outlined by the emulsion, and is shown to be of normal contour, i.e. there

is no filling-defect, but the opacity is faint and uneven. On palpation and change of posture it is possible to effect slight displacements of the foreign body, the emulsion then collecting in that part of the lumen which is no longer occupied. This appearance is very characteristic. Moreover, the hair-ball may be displaced into the cardiac extremity of the viscus, and will then show as a faint rounded opacity outlined against the gas-bubble there present.

The **gastro-jejunostomized stomach** presents a problem of considerable interest and difficulty to the radiologist—of interest because he is frequently asked to investigate unsatisfactory postoperative results, and of difficulty inasmuch as he often fails to find any cause for adverse symptoms.

If a patient be examined with an opaque meal within a few weeks of gastro-jejunostomy it will generally be found that the barium emulsion passes through the stoma in a practically uninterrupted stream, appearing in the jejunum as a dense, uniform opacity readily distinguished from the segmented jejunal contents of the normal individual. In spite of this rapid egress through the stoma, it is quite unusual for the gastric contents to leave entirely by this route ; a considerable quantity passes through the pylorus and duodenum unless the most intense pyloric obstruction is present.

After a variable interval the gastro-jejunostomy stoma appears to develop a considerable degree of sphincteric control ; the passage of the meal through this opening is then intermittent, and this condition of affairs, once established, apparently remains throughout the life of the individual. It is sometimes stated that in later years the stoma may cease to function entirely ; but such cessation of function is found in conjunction with adverse symptoms, and is not seen, in the author's experience, in those whose relief is complete. It is probable, however, that the sphincteric control of the stoma becomes more marked with the passage of time, and that in the absence of any pyloric obstruction a considerable proportion of the meal tends to follow the physiological channels.

The recently gastro-jejunostomized stomach empties with considerable rapidity, modified at a later stage by sphincteric control of the stoma.

It is unusual, in the absence of adverse symptoms, to find any appreciable gastric residue at the end of three hours, while a six-hour residue can be taken as definite evidence of the mechanical failure of the operation.

Failure to establish sphincteric control of the stoma occurs in a fair proportion of gastro-jejunostomized persons, and in some few of these results in discomfort after food. This discomfort may amount merely to a feeling of slight uneasiness, or may be so
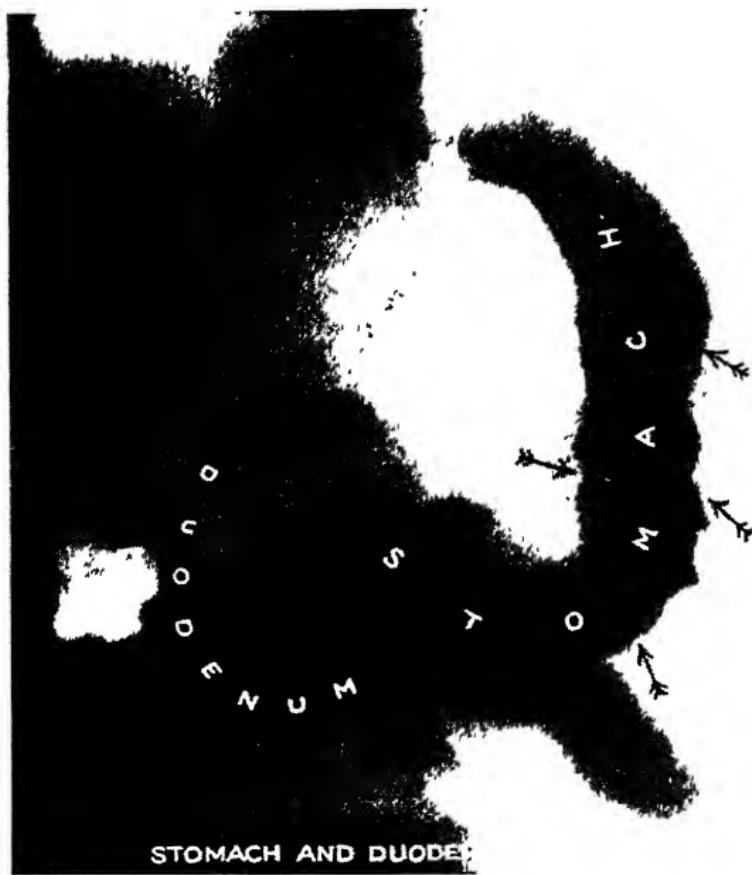
Fig. 1.—Scirrhus carcinoma of stomach.

Fig. 2.—Gastro-jejunal ulcer.

PLATE 72.

severe as to produce the most profound distress. Hurst was the first to point out that this sequel of gastro-jejunostomy results from distension of the jejunum and is not associated with retention in the stomach.

Delay in emptying of the stomach may result from contraction of a stoma originally too small ; more commonly it is found that the delay occurs only in the later stages of evacuation, and is due either to the stoma being too high on the posterior wall, or to an unduly short afferent jejunal loop holding up the stoma in a low fish-hook stomach. In either case the stoma is thrown out of action when the gastric contents fall below the level at which it is situated.

It is not always immediately apparent whether gastric contents are passing through the stoma or not in those cases where a free efflux occurs through the pylorus. The contents which travel via the duodenum necessarily appear at the stoma in their passage through the jejunum. It will be noted, however, that opaque material which has passed through the pylorus and duodenum presents a finely divided striated appearance in the jejunum, while jejunal contents derived directly from the stomach show a dense uniform opacity.

Obstruction of the jejunum may result from adhesions around the site of operation, or from kinking of a too long or too short afferent loop. The whole duodenum becomes distended with opaque contents ; the afferent loop presumably shares in the distension, but can rarely be demonstrated. The passage of the meal past the stoma is very slow, or may for a time be completely arrested. Small quantities may pass directly from the stomach through the stoma, but usually the artificial opening appears to be thrown completely out of action. It is not unusual for these jejunal obstructions to be intermittent, depending probably on the degree of distension of the stomach and adjacent portions of the alimentary tract. A second examination may therefore demonstrate an obstruction not seen on the first occasion.

Gastro-jejunal ulcer can sometimes be visualized in serial skiagrams as a persistent niche, or filling-defect (probably due to local spasm), in the region of the stoma. Failure to demonstrate the ulcer is by no means uncommon owing to the general obscurity produced by overlapping shadows. (Plate 72, Fig. 2.) The functioning of the stoma is not apparently affected, as a general rule, by the presence of an ulcer.

Duodenal ulcers.—Ulcers of the first part of the duodenum are recognized by a constant deformity of the duodenal cap. The constancy of the abnormality should be demonstrated by serial skiagrams, bearing in mind that some variations must necessarily occur when the cap is in process of emptying or filling—i.e. skiagrams are only

exactly comparable which show the same phase of the duodenal cycle. The deformity may represent the abnormality in contour produced by the ulcer, but is much more often largely spasmodic in origin. In many cases true ulcer deformity and spasmodic deformity can both be made out.

The spasmodic nature of the abnormality does not confuse the issue as in spastic conditions of the stomach, since persistent spasmodic contractures of the duodenum are practically pathognomonic of an organic duodenal lesion.

The duodenal cap may present a great variety of deformities in the presence of ulcer, but the following classification includes all the more characteristic malformations :

(1) A niche.

(2) An accessory pocket.

(3) A filling-defect.

These comprise the actual deformities of the lumen of the ulcer, and correspond exactly to similar appearances of the stomach. The niche is not very common, and the accessory pocket is exceedingly rare, and must not be confused with a diverticulum. The filling-defect is often seen (Plate 73, Fig. 1), nearly always on the inner border of the cap. These deformities are generally associated with the following :

(4) A spasmodic incisura of the outer border of the cap situated opposite the ulcer, and constant both in its presence and its intensity. (Plate 73, Fig. 2.)

(5) Multiple spasmodic contractures, producing stellate or completely irregular cap-formations. (Plate 73, Fig. 3.)

(6) A uniform contraction of the first part of the duodenum, no proper cap-formation being observed although the meal leaves the stomach with normal or undue rapidity. This must be distinguished from the imperfect distension of the duodenum which is seen when, as a result of defective gastric motility, pyloric spasm, or actual pyloric stenosis, the meal leaves the stomach in small quantities.

These three spasmodic deformities are all very common, and constitute the bulk of the malformations which justify a diagnosis of duodenal ulcer.

(7) Occasionally a spasmodic incisura is seen in the base of the cap, i.e. the surface formed by the pyloric sphincter. The method of formation in this situation is not easy to understand, but the occurrence of the deformity is undoubted.

In the earlier stages of pyloric stenosis it is often possible to demonstrate the deformity of the causative lesion in the stomach or duodenum. In cases of advanced obstruction, however, the first part of the duodenum is so imperfectly filled by the opaque material that no opinion can be formed as to its condition.

Fig. 1.—Small duodenal ulcer.

Fig. 2.—Duodenal ulcer, filling-defect and spasmodic incisura.

Fig. 3.—Duodenal ulcer, multiple spasmodic contractures.

PLATE 73.

Ulcer of the duodenum is often associated with hyperperistalsis and rapid emptying of the stomach. Great weight used to be attached to these indirect signs, and if present they certainly afford confirmatory support to the diagnosis ; in quite 50 per cent. of duodenal ulcers, however, the stomach fails to show any particular functional abnormality, while, on the other hand, hyperperistalsis and rapid emptying are exceedingly frequent phenomena in the absence of any organic duodenal lesion. It is obvious, therefore, that the diagnosis of ulcer must depend entirely on successful demonstration of a cap deformity.

Duodenal ulcers are seen much more frequently in association with an orthotonic or hypotonic stomach of fish-hook shape than with the transverse hypertonic form of stomach ; in other words, there appears to be no increased liability of the hypersthenic individual to suffer from this lesion. Occasionally the fish-hook stomach shows increased tone in the presence of duodenal ulcer, but this is too infrequent and anomalous to be of any real diagnostic significance.

Ulcers of the second part of the duodenum are very rare. In the few reported cases in which radiographic diagnosis was possible the deformity appears to have been of the niche type.

Differential diagnosis.—The deformities of duodenal ulcer must be distinguished from those due to—

(1) Periduodenal adhesions.

(2) Pressure on the duodenum by the gall-bladder or pancreas.

(3) Duodenal diverticulum.

(1) *Periduodenal adhesions* often result in an irregular crenation of the borders of the cap, varying in degree with the position of the patient. (Plate 74, Fig. 1.)

This effect of posture is fairly conclusive evidence that the deformity does not depend upon an intrinsic lesion, and the conclusion is supported by observation of displacement or definite fixation of the gut.

Unfortunately, however, adhesions are sometimes productive of deformities practically identical with those of ulcer. The differential diagnosis then presents the greatest difficulty, and may in fact be impossible. Usually it will be observed that in cases due to adhesions the deformity becomes less marked as the stomach empties, while deformity resulting from ulceration shows no such change.

It must not be forgotten that periduodenal adhesions and ulcer frequently coexist.

(2) *Pressure on the duodenum* by a distended gall-bladder produces a characteristic crescentic indentation in the lumen of the bowel ; the effects of lesions of the biliary tract upon the duodenum are more fully discussed in a later chapter (p. 211). (*See* Plate 79, Fig. 1.)

Pressure on the duodenum by enlargement of the head of the pancreas occurs typically in carcinoma of this gland. The deformity

of the cap may closely simulate that of ulcer, but in association with this will be found a characteristic centrifugal displacement of the second, third and fourth portions of the duodenum, often combined with some degree of dilatation of these more distal segments. The appearances are so typical that their recognition justifies a definite diagnosis of pancreatic disease.

(3) *Duodenal diverticulum* may closely simulate the accessory pocket deformity of duodenal ulcer. Duodenal diverticula are by no means uncommon, are frequently multiple, and generally arise from the inner aspect of the second part of the duodenum, or less frequently from the outer or under aspect of the first part. Their presence is not associated with any other duodenal abnormality.

Accessory-pocket formation by a duodenal ulcer is exceedingly rare, and is apparently never multiple. The pocket is usually connected with the inner border of the first part of the duodenum, and is frequently associated with spasmodic deformities of the cap.

Healing of a duodenal ulcer results in disappearance of any spasmodic element in the deformation ; in some instances the cap presents no evidence of the former lesion whatever, but more often a small filling-defect indicates the presence of scarring.

Should repeated examinations elicit the gradual diminution and final disappearance of spasm, the residual filling-defect may be disregarded and the ulcer considered to be healed.

When, however, a small filling-defect represents the only deformity seen at the first examination of the patient, the distinction between an active ulcer and a scar-formation is exceedingly difficult, and often quite impossible. Hypermotility of the stomach, if present, is of value in indicating activity of the lesion, provided that early pyloric stenosis can be definitely excluded. In the absence of this sign it is rarely justifiable to make any more definite statement than that the appearances are *consistent* with a healed lesion, but that activity cannot be excluded.

Duodenal carcinoma is so rare that no data are available as to radiographic diagnosis. The growth would certainly produce a filling-defect in the lumen of the gut, but this would probably be indistinguishable from the deformities of ulceration or periduodenal adhesions.

Duodenal ileus.—Obstruction of the third part of the duodenum in the mid-line is not uncommon, and usually results from formation of a band in the mesenteric attachment, or from pressure of the superior mesenteric vessels in severe enteroptosis.

Extreme instances of duodenal ileus present radiographic appearances so striking as to preclude any difficulty in diagnosis ; the whole of the duodenum proximal to the obstruction fills up with opaque

Fig. 1.—Adhesions deforming first part of duodenum.

Fig. 2.—Duodenal ileus.

Fig. 3.—Congenital dilatation of colon (Hirschsprung's disease), mild degree

PLATE 74.

emulsion and is seen to be enormously dilated. Occasional vigorous peristalsis may be observed with long intervening periods of complete immobility. As small quantities of barium pass into the distal portion of the gut it is possible to elicit the fact that the bowel is not uniformly constricted at the site of obstruction, but is flattened against the spine. (Plate 74, Fig. 2.) Regurgitation of duodenal contents into the stomach cannot be demonstrated owing to the fact that both viscera are filled with opaque material.

If observations are continued at six or eight hours, or later, a duodenal residue may be seen for some time after the stomach is empty.

In less advanced cases of ileus the duodenum proximal to the obstruction shows marked dilatation and vigorous peristalsis ; the contents of the proximal gut undergo to-and-fro movements which are greatly in excess of those normally seen. Retention in the duodenum may not be very prolonged, but the flattening of the bowel against the spine should be quite obvious. This flattening of the duodenum forms the essential observation in mild cases of ileus, the other appearances of which differ only in degree from the normal.

It is noteworthy that duodenal ileus, especially in its milder form, is frequently intermittent, and may therefore evade detection unless the examination is repeated on a subsequent occasion.

In all frank cases of duodenal ileus the obstruction affects the third or transverse part of the duodenum in the mid-line, as described above. The writer has never seen obstruction, or even the most transient delay, occur at the duodenal-jejunal flexure.

THE JEJUNUM AND ILEUM

While no definite delimitation of the jejunum from the ileum is possible, the upper and lower portions of the small gut, when containing barium emulsion, present several distinctive features.

The *jejunal coils* occupy chiefly the left side of the abdomen, especially above the level of the iliac crest. The contents become rapidly and widely scattered throughout the coils within a comparatively short time after ingestion of the meal, provided that gastric and duodenal evacuation is proceeding normally. Hence individual coils do not, by retention, become distended, and this results in the valvulæ conniventes being outlined as transverse and reticular striations against the scattered barium contents.

Peristalsis is exceedingly active in the jejunum, and appears as wide waves of contraction which usually pass with considerable rapidity over a segment of gut 6–12 inches in length, and then fade away, to be rapidly followed by another wave which does not necessarily commence or terminate at the same points. Occasionally a single rapid

peristaltic wave may be observed to pass over a much longer segment of gut. Peristalsis in the small gut does not follow an orderly sequence as in the stomach, but is very irregular.

Antiperistalsis does not appear to occur in normal circumstances, but to-and-fro movements are induced by escape of some proportion of the jejunal contents backwards through the advancing constriction-ring.

Apart from the peristaltic movements described above, the jejunum also undergoes stationary annular contractions, whereby the lumen is periodically divided into a number of short segments. This segmentation is, however, of rare occurrence as compared with peristalsis, and in many cases is not observed at all.

The *ileal coils* chiefly occupy the right side of the abdomen and the pelvis. Peristalsis is slower and less frequent, and each wave commonly extends over no more than 3–4 inches of the gut. The lower ileum often shows inactivity over considerable periods. Segmental contractions are not observed.

The barium contents of the ileum tend to show a dense uniform opacity, partly as a result of the paucity of the valvulæ conniventes, but largely on account of the definite retention and accumulation which occurs in this portion of the bowel.

The terminal coil of the ileum usually ascends from the pelvis along the inner side of the cæcum. Sometimes the junction presents a horizontal T-shape, the ileum being more or less transverse in position, while occasionally the ileal coil forms a loop convex upwards, the terminal few inches of the small gut descending to an oblique junction with the cæcum.

Immediately proximal to the ileo-cæcal valve the ileum commonly shows a fairly tight constriction extending over the terminal $\frac{1}{4}$–$\frac{1}{2}$ inch of the lumen. This only relaxes to permit of influx into the cæcum, and in fact appears to indicate a definite sphincteric control ; on this supposition it is often spoken of as the " ileal sphincter."

All the coils of small bowel available to adequate palpation, from the upper jejunum to the terminal ileum, are freely mobile in the normal individual. It is often exceedingly difficult to displace coils which are situated deeply in the pelvis in enteroptosis, and failure to achieve such displacement must not be interpreted as indicating pelvic adhesions. Abdominal palpation with the patient prone, especially if the pelvis is raised, frequently succeeds in displacing the ptosed bowel from the true pelvis and thus demonstrating its mobility.

The rate of passage of the opaque contents through the small intestine varies in different individuals, and is also markedly influenced by the rate of emptying of the stomach, while no useful observations can be recorded should the patient have taken an aperient within

twenty-four hours of the examination. Under normal conditions, the stomach being empty in four to six hours, the head of the opaque column should be seen in the terminal ileum in about three hours after ingestion of the meal. The cæcum usually starts to fill one to one and a half hours later. Influx into the cæcum is sometimes determined by the ingestion of food, this phenomenon being named by Hurst* the " gastro-ileal reflex," but in the author's experience it is exceedingly unusual to observe any such effect on giving the second meal of the six-hour meal technique.

The small intestine is generally free of opaque contents in seven to ten hours after the meal, provided no delay occurs in the stomach.

Diverticula of the small gut. — Multiple diverticula are sometimes seen in connexion with the jejunum and ileum, and present small rounded opacities projecting from the lumen. In individuals who present this abnormality it is usual to find diverticula also in the duodenum and colon ; this widespread formation of diverticula from the small and large intestine appears to be of developmental origin.

Meckel's diverticulum can rarely, if ever, be recognized owing to the difficulty of distinguishing a blind loop among the intricately mingled and closely packed coils of the lower ileum.

Adhesions and bands around the small bowel not infrequently fail to produce any demonstrable abnormality on radiographic examination.

The following appearances are indicative of involvement of the small gut in adhesions or band-formation : (1) Definite retention in some coil or coils. (2) Dilatation and hyperperistalsis in a segment, and deformity of its extremities. (3) Persistent deformity (e.g. angulation) of a coil of gut. (4) Definite fixation of a segment of the gut. Should all these signs be elicited, the diagnosis of involvement in some obstructive lesion, probably adhesions or bands, can be made with confidence. The presence of any one of the signs, however, does not justify such a diagnosis unless the abnormal appearances can be confirmed by subsequent re-examination.

Angulations or " kinks " of the small bowel, unless attended by definite dilatation, hyperperistalsis and retention of contents, usually possess no clinical significance.

Indubitable evidence of widespread adhesions, involving many coils of jejunum and ileum, is suggestive of tuberculous peritonitis in the absence of any history of a general peritoneal infection due to some other organism.

* " Constipation and Allied Intestinal Disorders."

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THE ALIMENTARY TRACT (*concluded*)

THE LARGE INTESTINE

Two methods are available for examination of the large intestine, the opaque meal and the opaque enema. Generally speaking, it is advisable to employ both methods, as one may supply valuable confirmatory evidence of the other; but if a choice must be made the enema is incomparably superior in the majority of cases, and forms an absolute essential in the investigation of suspected organic disease of the large bowel.

The appearances of the bowel as seen by the two methods are very different, and require separate consideration.

Normal appearances with the opaque meal.—Examinations should be made about the fourth and eighth hours after the meal (these observations being replaced by one at the sixth hour if the six-hour meal method is adopted), and again at the twenty-fourth and forty-eighth hours ; later, daily examination may be necessary in cases of colonic delay, the patient abstaining from any aperient medicine until the investigation is completed.

There is nothing to be gained by more frequent visits to the X-ray room : the passage of the meal through the colon is singularly insusceptible to hard-and-fast rules, and what is required from observation of the meal is a broad conception, not a mass of detail which defies correct interpretation. Detailed investigation of the lumen of the bowel necessitates administration of an opaque enema—it is quite impossible of accomplishment by means of the meal, however many examinations are made. The position of the large gut varies greatly in different individuals, and is also dependent to some extent in any one person on the colonic contents and condition of the small intestine at the time of the examination. The greatest normal variations are seen in the cæcum and ascending colon, which appear to be much less influenced than the remainder of the gastro-intestinal tract by the habitus of the subject. In hypersthenics and sthenics the hepatic flexure may lie at the level of the right anterior costal margin, but is much more commonly situated about 1 inch above the iliac crest in the upright position, and sometimes very much lower. In those of less robust physique the hepatic flexure rarely lies more than 1 inch above the crest, and more often at a slightly lower level. Since some

limits to the normal must be recognized, it is usual to speak of *ptosis* if this flexure lies at or below the level of the iliac crest, but there can be no doubt that the low position is often developmental, and is not inconsistent with the maintenance of perfect health and normal function. Radiological investigation of sufferers from ptosis whose symptoms are relieved by the wearing of an abdominal support leads to the conclusion that symptoms do not arise from the low position of the bowel in itself, but from a superadded failure of intra-abdominal pressure, as a result of which the weight of the colon is transmitted in part to the mesentery and its contained vessels and nerves. In point of fact, belts and corsets designed to correct coloptosis rarely effect an anatomical amelioration of more than half an inch as regards the position of the hepatic flexure, although, as is well known, the clinical result may be highly satisfactory.

Undescended cæcum is comparatively rare. The terminal ileum is observed passing upwards to the position normally occupied by the hepatic flexure, and the cæcum can be demonstrated immediately below the liver. The ascending colon is usually very short in these cases, the cæcum appearing to empty directly into the transverse colon.

The transverse colon in hypersthenics and many sthenics is short, and presents little downward convexity. In hyposthenics and asthenics, on the other hand, the transverse colon forms a long loop which usually descends nearly to the upper border of the symphysis pubis. It appears unlikely that the length and position of the transverse colon possesses any clinical significance.

The splenic flexure normally lies high up under the left costal margin, and is frequently retained in that position by its ligamentous attachment in subjects whose hepatic flexure is seen in the iliac fossa. *Ptosis of the splenic flexure*, although it has received but scanty attention, would appear to constitute a much more definite abnormality than a low position of the proximal colon.

It is worthy of emphasis that ptosis of one or other part of the colon is not attended by obstructive kinking of the hepatic and splenic flexures, as can be plainly demonstrated by viewing these parts with the patient in a lateral position.

The descending and iliac colons are usually in direct contact with the posterior abdominal wall and iliac fossa, and present no variation in length. Occasionally, however, a loop is seen in the descending colon, provided with a mesentery, the two limbs of the loop being closely applied ; while in other subjects the iliac colon may appear to be absent, the free loop of the pelvic colon joining the descending segment at the iliac crest.

The pelvic colon presents every degree of variety from a short, slightly curved segment of gut passing almost directly between the

rectum and iliac colon, to a loop 12 or more inches in length. These variations in length of the pelvic colon are congenital; a long pelvic colon possesses no clinical significance unless the gut shows concomitant and unmistakable dilatation.

The rectum is not ordinarily seen by the opaque-meal method of examination, since entry of intestinal contents into the part normally excites the desire for defæcation.*

The tone of the large bowel varies in its different parts. The cæcum and ascending colon usually exhibit the least evidence of tone, being comparatively free from sacculation and apparently acting as a reservoir for the fluid contents entering from the ileum. The transverse colon also retains a considerable quantity of material, but shows well-marked sacculation along its whole length. Deficiency or absence of sacculation in this part of the bowel is indicative of atony; unusual prominence of sacculation does not appear to be of any clinical significance.

The descending colon is most often in a state of uniform tonic contraction, and is then seen to contain but small quantities of opaque material; in other words, this segment of gut does not ordinarily act as a reservoir for intestinal contents, but only undergoes complete relaxation temporarily and at long intervals in synchronism with contraction of the more proximal parts of the large bowel. Occasionally the descending colon is seen well filled and with definite sacculations, but this probably indicates some degree of atony if it occurs as a constant appearance.

The pelvic colon often retains considerable quantities of the opaque meal, and may then show little evidence of sacculation. If small quantities only are present, these usually appear as small isolated masses indicative of well-marked sacculation.

The demonstrable mobility of the large gut depends in part on the presence or absence of a mesentery, and in part on intra-abdominal pressure. Mobility is tested by observing the relative positions of the colon in the upright and supine positions, and by palpation in the latter posture.

The cæcum is quite movable, and the ascending colon often presents a degree of mobility which indicates the presence of a definite mesentery, although slight retroperitoneal mobility may occur. The transverse colon is mobile in proportion to its length and the freedom of movement of the hepatic and splenic flexures. In no circumstances, however, should any part of the transverse colon between the flexures show definite fixation. Normally the splenic flexure is, for practical purposes, fixed in position; a demonstrable mobility of 2 inches can be regarded as indicative of ptosis. The descending colon shows very slight mobility.

* A. F. Hurst, " Constipation and Allied Intestinal Disorders."

Hence it will be seen that *definite* fixation of the transverse colon or cæcum, and usually of the ascending and pelvic colon, can be regarded as indicative of adhesions. Resistance to palpation renders the determination of fixity a matter of considerable difficulty, and in such circumstances reliance must often be placed on the appearances in the upright and supine postures alone. Extreme increase of mobility is demonstrated in definite coloptosis; it is also seen in "cæcum mobile," which results from the presence of a long mesentery for the cæcum and ascending colon, but appears to possess no clinical significance.

The motility of the large bowel is strikingly different from that of the upper parts of the alimentary tract. Muscular contractions occur only at long intervals, probably three or four times during the twenty-four hours, and last for no more than a few seconds. In the long intervals which elapse between the contractions the bowel appears completely inert. Movement of the colonic contents is therefore rarely noted during observations of the meal, but is readily seen after administration of an opaque enema, although in this case some allowance must be made for the abnormal conditions imposed on the bowel.

Typically, contraction of the large gut appears as a uniform constriction affecting every part of a considerable segment simultaneously. Occasionally the constriction does not appear as a simultaneous contraction of the segment, but as a very rapidly travelling wave ; the subsequent relaxation does not, however, assume the wave form, but occurs, so far as can be made out, simultaneously over the whole segment a few seconds after uniform contraction has been established.

This contraction of the gut results in extensive movement of the contents, known as "mass movement." Quite frequently a large proportion of the contents proximal to the splenic flexure is propelled by a single contraction into the pelvic colon, and when this occurs relaxation of the descending colon, and subsequent gradual resumption of tonic contraction, can be observed.

The segment of gut which has undergone this sudden, possibly peristaltic constriction relaxes rather slowly, and after a lapse of some seconds resumes its sacculated outline, as shown by the formation of the scanty residual contents. Mass movement is sometimes excited by the ingestion of food, but attempts to promote the phenomenon by this means during X-ray examination are rarely successful.

In addition to mass movement, small localized waves have been described as occurring fairly constantly in the colon, but the existence of such waves is open to considerable doubt.

The rate of passage of the meal through the large intestine varies within wide limits from day to day in any one individual. This is readily understood when consideration is given to the nature and

infrequency of the intestinal contractions. It is obvious that two examinations within a few seconds of each other might reveal an entirely different disposition of the meal, and therefore it is quite impossible to lay down any definite standard by which the motility of the large gut may be judged.

Examination of a large number of individuals, however, enables some conception to be formed of average appearances, but only persistent, gross variations from the average, noted over successive examinations, can be regarded as constituting a definite abnormality.

With this proviso, it may be stated that the cæcum commences to fill with opaque material within six hours of ingestion, provided that no abnormality, either gastric or intestinal, retards the passage of the meal to the lower ileum. Frequently the cæcum, ascending colon and part of the transverse colon are filled at the sixth hour, less often the head of the opaque column is seen in the descending colon. Failure to observe any barium in the large bowel at the sixth hour may be taken as definite evidence of ileal delay, if the conditions of passage to the lower ileum noted above are fulfilled.

At eight hours the head of the opaque column is usually seen in the transverse colon towards the splenic flexure, while at twenty-four hours the pelvic colon should be reached. As previously noted, it is unusual to see the descending colon in a state of distension, so that the most common appearance at twenty-four hours consists of a loaded transverse colon, considerable quantities in the pelvic colon, and traces in the descending colon. The cæcum and ascending colon are frequently loaded with opaque material, but sometimes show evidence of partial emptying, i.e. in place of a dense uniform opacity a scanty and uneven distribution of barium is seen in the proximal colon. At forty-eight hours a good deal of the meal has generally been evacuated. The residue may be scattered throughout the whole of the large bowel as a scanty uneven deposit, or may be chiefly aggregated in the transverse and pelvic colons. At seventy-two hours practically no traces of the meal remain.

Defective motility may result in a general slowing-down in the advance of the head of the opaque column. More often the initial rate of transit is quite normal, the head of the opaque column being seen about the splenic flexure or upper part of the descending colon by the eighth hour, but the passage through the more distal portions of the gut is delayed and of a piecemeal nature. At other times the greater part of the opaque material is evacuated within a normal period, but prolonged retention of a considerable residue is observed in the cæcum and ascending colon. It would appear probable that these variations, if sufficiently marked to constitute an undoubted abnormality, are due to atony affecting all or some part of the bowel.

Occasionally a spasmodic element may be present, producing inhibition of the passage through the distal portions of the bowel ; this is probably very rare, and owing to the normal tonicity of the descending colon its occurrence can hardly be inferred from observations of the opaque meal alone.

Delay in evacuation of the meal sometimes depends upon retention in the rectum, which acquires, as a result of defective habit, a degree of insensibility to the stimulus of contained fæcal material normally productive of defæcation. In these cases the passage of the meal through the colon is normal as far as the pelvi-rectal junction, but a definite and often very large quantity of opaque material is seen in the rectum. This constitutes the rectal type of constipation described by Hurst.*

The opaque enema.—Administration of an opaque enema forms an essential part of the radiographic examination of the large bowel, as only by this means is it possible to ensure maximum distension of every part of the lumen, and so demonstrate the presence or absence of organic deformities.

The opaque-enema technique, to possess its proper value, depends to a considerable extent on efficient preparation of the patient. The large bowel should be completely empty, and this end is best attained by administration of a dose of castor oil the day before the examination, followed by one or more colonic washouts, the last within an hour or two of the visit to the X-ray room.

The opaque enema is given by means of a douche-can and long rectal tube, the latter being passed not more than 4 inches through the anus (attempts to pass a tube past the pelvi-rectal junction are uniformly unsuccessful, and result in the curling up of the tube in the rectum with subsequent obstruction to the flow of liquid). The douche-can is raised 2 or 3 feet above the level of the X-ray couch, the height being adjusted so as to maintain a steady but rather slow injection. Rapid injection causes discomfort and may defeat its own ends by rendering the patient unable to retain the enema after the lower bowel has been distended. In the absence of any obstruction the entire colon should be filled within a space of five to ten minutes. The lumen is visualized as a smooth-walled, perfectly regular tube, attaining its greatest diameter in the cæcum and ascending colon. Very commonly some of the enema passes through the ileo-cæcal valve into the lower coils of the ileum. This cannot be regarded as abnormal. The filling of the large bowel should be observed on the screen, as not infrequently the completely distended coils overshadow each other to some extent, and thus a demonstrable lesion may be obscured in skiagrams taken when administration is completed. Palpation of the bowel under screen examination is also useful in

* " Constipation and Allied Intestinal Disorders."

separating superimposed coils of gut, testing mobility, etc. Within a few minutes of discontinuing the injection, or even before the process is completed, sacculation reappears in the distended bowel. It is important that skiagrams be obtained before this occurs.

Examination after attempted evacuation of the enema is sometimes helpful; it will be found that complete evacuation is never accomplished at the first attempt.

Difficulty in attaining a ready flow of the enema in normal individuals is usually due to kinking of the tube in the rectum. It may also arise from an airlock in the tube, or from the presence of fæcal material in the colon in patients insufficiently prepared. Organic lesions of the large bowel are shown as filling-defects or other deformities of the lumen, or occasionally may completely obstruct the further passage of the injection.

Correct interpretation of the appearance of the opaque enema is sometimes a matter of considerable difficulty. In the first place, it must be recognized that an organic lesion (e.g. neoplasm) confined to the anterior or posterior wall of the rectum may produce no recognizable abnormality, since the part of the lumen involved cannot be seen in profile. There is also no question that very small growths involving the portions of the gut proximal to the rectum may escape detection for the same reason—i.e. restriction of the resultant filling-defect to an aspect of the lumen not readily visualized. Another frequent source of difficulty consists in failure of the injection to pass the splenic flexure in subjects free from any organic disease. This is apparently due to the distended distal limb of the flexure pressing into the empty proximal loop; turning the patient upon the right side generally relieves the artificially produced obstruction.

A collection of gas in the iliac colon may cause temporary suspicion to fall upon this segment of gut, the enema flowing round the gaseous content and so failing fully to distend the lumen. Palpation under screen examination should resolve all doubts on this subject, by displacing the gas-bubble from one area to another and so ensuring satisfactory filling of all parts of the lumen in turn.

Occasionally a patient will be encountered who is quite unable to retain any considerable quantity of the injection; in these cases it will be observed that return of the enema does not follow extreme distension of the distal bowel, but occurs before any considerable rise of pressure has been effected in the parts filled.

Abnormalities of the large bowel. Megacolon.— Congenital dilatation of the colon, or Hirschsprung's disease, may affect chiefly the lower part of the bowel above the rectum, but it is far more common to find a fairly uniform change throughout the

whole of the large intestine as far as the pelvi-rectal junction ; the rectum generally remains comparatively normal.

Investigation with the opaque meal does not afford an adequate estimate of the colonic dilatation, but reveals an extremely slow progression of the opaque column throughout every part of the large gut. The opaque enema fills the bowel slowly, owing to the remarkable dilatation, and ten or more pints may be required to secure distension of the cæcum. In addition to the dilatation the intestine is often seen to be enormously elongated, with the result that it is impossible to distinguish the true disposition of the coils when injection is completed. As much of the barium emulsion as possible should be siphoned off by lowering the douche-can when the examination is finished, otherwise the greater part will be retained in the atonic gut, and by absorption of the suspending water will form into hard masses liable to accentuate the constipation from which the patient already suffers. (Plate 74, Fig. 3.)

Colitis.—In cases of *mucous* colitis it is quite unusual to observe any radiographic abnormality. In a small proportion of cases the whole or part of the bowel shows a remarkable paucity of haustration, but this can hardly be considered pathognomonic of the disease. In *ulcerative* colitis, on the other hand, a very striking constriction of the lumen is generally observed. This often affects the whole of the colon, and is then more or less uniform ; at other times only a segment of the gut is constricted, but the area involved is always much more extensive than in other organic lesions. The contraction of the bowel is not affected by administration of belladonna, and is probably in part organic, due to inflammatory infiltration ; but it is difficult to believe that spasm is not an accentuating factor. In spite of the narrowed lumen, there is no obstruction to the passage of the enema, which in fact reaches the cæcum with remarkable rapidity. *Fibrous strictures* resulting from ulcerative colitis appear as localized annular constrictions of the lumen, frequently multiple. The gut immediately adjacent to the constriction does not show the irregular filling-defects which are observed in neoplastic strictures.

Tuberculosis of the large gut is generally localized to the cæcum and ascending colon, where it results in an inflammatory mass encroaching upon and often almost obliterating the lumen. On investigation by means of the opaque meal it is seen that there is considerable ileal delay, and that the opaque material eventually appears in the transverse colon, which fills normally, the lumen of the proximal colon being indicated only by a thin tortuous stream. This extensive filling-defect of the proximal colon, whereby an almost complete hiatus appears to exist between the barium shadow of the ileum and that of the transverse colon, is known as *Stierlin's sign*,

and has been described as pathognomonic of ileo-cæcal tuberculosis. Precisely similar appearances may sometimes be produced, however, by neoplasm of the proximal large gut. The opaque enema confirms the abnormality demonstrated by the meal.

Colic diverticula are very common, and are often confined to the descending and pelvic colon, although in other instances the entire colon may be affected, sometimes in association with diverticula of the small bowel. The diverticula are seen as small round opacities, rarely larger than a pea, lying outside the lumen of the gut. These little hernial pouches of the colonic mucosa are filled more frequently during investigations with the meal than with the enema ; with either medium, examination after the bulk of the opaque material has been evacuated often reveals many additional diverticula which have been overshadowed and obscured by the barium contents of the lumen. (Plate 75, Fig. 1.)

Small barium collections cut off by sacculation from the central part of the lumen may simulate diverticula, but their disappearance on subsequent distension with an enema will establish their true nature.

In diverticulitis, examination by means of the opaque enema demonstrates a filling-defect in the lumen of the bowel. This defect is usually several inches long, and shades off gradually at either extremity into the normal lumen, these two characteristics being of value in differentiation from malignant neoplasm. The segment of bowel affected is nearly always a portion of the pelvic or the iliac colon, and the lumen is often reduced to an exceedingly narrow, tortuous channel. Diverticula are rarely demonstrated in connexion with the stricture, their communication with the lumen being closed by the inflammatory thickening of the surrounding tissues, but they may be seen arising from the adjacent portions of the gut. It must be remembered, however, that colic diverticula may coexist with a neoplasm.

In the absence of demonstrable diverticula or of definite stricture, a peculiar outline of the lumen, aptly described as the " saw-tooth " deformity (Plate 75, Fig. 2), is strongly suggestive of a commencing diverticulitis.

Adhesions involving the large bowel are indicated by fixation of some part normally mobile, with or without some degree of deformity. In point of fact, definite deformity is rather rare as a result of adhesions, and when present is generally seen as a compression of the lumen in one plane only, the gut appearing flattened without any concentric constriction.

Neoplasms of the large intestine may be either benign or malignant.

Benign polyps ordinarily afford no radiographic indication of their presence. Extensive polyposis of the colon may result in widespread

Fig. 1.—Colic diverticula.

Fig. 2.—Diverticulitis: saw-tooth outline of descending colon.

PLATE 75.

Fig. 1.—Carcinoma of cæcum and ascending colon.
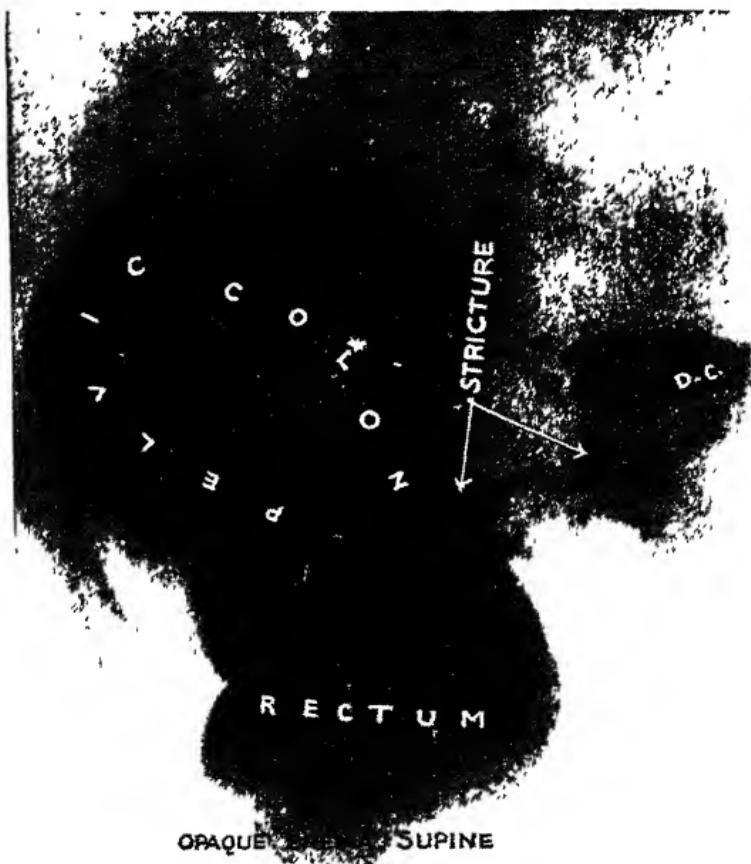
Fig. 2.—Carcinoma of pelvic colon.

PLATE 76.

irregular mottling of the colon when filled with the opaque enema.*
These cases are excessively rare.

Malignant growths are mostly carcinomatous, but no distinction be-
tween colonic carcinoma and sarcoma is possible from the X-ray appear-
ances. These neoplasms produce filling-defects in the colon, as in the
stomach. The defect may involve part of the circumference of the bowel
only, or may be of annular form. As previously pointed out, a small
defect limited to the anterior or posterior aspect of the gut is very
liable to escape detection, and a negative finding is therefore of little
value in cases where the history is consistent with a very early growth.

Malignant neoplasms of the cæcum and ascending colon are equally
well demonstrated by the meal and the enema. The filling-defect
produced may exactly simulate the appearances of tuberculosis, the
lumen of the proximal gut being almost obliterated by an annular
constriction, resulting in an almost complete absence of opaque material
between the ileum and transverse colon. Far more frequently, how-
ever, the growth projects into the anterior or posterior aspect of the
lumen, and the scanty barium contents of the cæcum and ascend-
ing colon are then seen to be spread out in an irregular layer
of more or less normal transverse diameter. Sometimes the cæcum
only is involved, and then this part may hardly fill at all. (Plate 76,
Fig. 1.)

Neoplasms of the transverse, descending and pelvic colons can
only be demonstrated by means of the opaque enema. The normal
appearance is that of a fairly localized stricture of the bowel ; the
outline of the lumen in the constricted portion is often regular, but
irregular filling-defects are seen at the junction of the normal lumen
and the stricture. These filling-defects, though usually quite well
marked, do not extend far from the annular stricture ; in other words,
the margins of the constriction tend to be rather abrupt, in contra-
distinction to the gradual shading-off of the inflammatory stricture
produced by diverticulitis. (Plate 76, Fig. 2.)

Should the enema fail to canaliculize the lumen through the growth,
the characteristic appearances of a neoplastic lesion will not be demon-
strated ; in these circumstances a diagnosis of obstruction can be made
but the cause cannot be specified. In cases of early neoplasm pro-
ducing a demonstrable filling-defect of one aspect of the lumen only,
serial skiagrams should be obtained while the injection is still
proceeding, with a view to confirming the constancy of the deformity.

THE VERMIFORM APPENDIX

No definite opinion can be formed as to the condition of the
appendix unless the lumen is canaliculized by opaque emulsion. In

* Carman and Miller, " Roentgen Diagnosis of Diseases of the Alimentary
Tract."

the absence of visualization, indications of adhesions (e.g. fixation-deformity) around the lower ileum or cæcum may suggest a chronic appendicular lesion, although the adhesions may, of course, be due to some less common inflammatory condition.   Ileal delay, frequently quoted as occurring in chronic appendicitis, appears to have very little, if any, actual relationship to this disease : the majority of patients with chronically inflamed appendices do not present any evidence of ileal delay, while in some subjects in whom delay has been noted subsequent removal of a diseased appendix has not been shown to affect the rate of intestinal transit.

By far the most valuable of these *indirect* signs does not depend on the opaque meal technique, but consists in the demonstration of calcified ileo-colic glands.   These glands lie in the region of the right sacro-iliac synchondrosis, or in the angle formed by the lumbar spine and right iliac crest, and their isolated calcification is strongly suggestive of an old appendicular lesion.

While the appendix is occasionally visualized during the administration of an opaque enema, the barium meal is the medium which should always be employed in these investigations.

It is advisable for the patient to take a dose of castor oil thirty-six hours before the meal, as this aperient seems to be particularly efficacious in promoting canaliculization.   The routine technique of opaque-meal examinations is adhered to, and careful search is made for the appendix at the first visit in which the cæcum is filled, and subsequently.

Palpation under the fluorescent screen is of great assistance in demonstrating the appendix, but skiagrams should also be obtained in all cases ; these not only elaborate the information gained from fluoroscopy but frequently reveal a canaliculized appendix which was not recognized on the screen.

Ptosis of the cæcum into the true pelvis presents a considerable difficulty, since the appendix, though filled, is unlikely to be seen. Every effort must therefore be made to displace the cæcum into the iliac fossa; this can often be effected by hypogastric palpation while the patient lies on the left side, or semi-prone; failing success by this method, inflation of the rectum with air will usually ensure the desired result.

Once the appendix has been seen filled, further examinations should be made at the usual intervals, and continued on the third and fourth mornings if emptying is delayed.

The **normal appendix** fills with the opaque meal in a large proportion of cases.   The method of filling from and emptying into the cæcum is apparently one of alternate antiperistalsis and peristalsis. Usually the appendix is seen at the eighth hour, but sometimes not till the twenty-fourth ; emptying may occur in a few hours, but usually

Fig. 1.—Normal appendix with regular lumen.

Fig. 2.—Normal appendix. Note segmentation.

Fig. 3.—Chronic appendicitis.

Fig. 4.—Abnormal appendix.

PLATE 77.

synchronizes with the disappearance of opaque material from the cæcum. Occasionally the appendix may be seen to fill, empty and fill again during the course of the examination. When completely filled, the lumen of the normal appendix is perfectly regular from base to distal extremity, or presents a number of orderly segmentations ; the diameter of the lumen varies from $\frac{1}{16}$-$\frac{1}{4}$-inch, or even more.

The appendix is freely mobile within the abdominal cavity on palpation, and can also be separated from the terminal ileum and, except of course at its base, from the cæcum. No fixed angulations or kinks appear in the lumen, and direct pressure under screen examination elicits no painful sensation. (Plate 77, Figs. 1, 2.)

The abnormal appendix.—Patients with acute appendicitis are not referred for X-ray examination, so that the following remarks apply only to the chronically inflamed organ, which is filled in a smaller proportion of cases than the normal structure.

Chronic appendicular disease is indicated by—
(1) Irregularity of lumen.
(2) Fixed kinks or angulations.
(3) The presence of concretions.
(4) Involvement in adhesions.
(5) Abnormal retention of contents.
(6) Localized tenderness on direct pressure.

(1) **Irregularity of the lumen,** if constant, probably constitutes the best evidence of abnormality. It must be remembered, however, that the process of filling and emptying will naturally be accompanied by some apparent irregularity ; hence it is necessary to confirm any supposed deformity by comparison of skiagrams taken at the different visits. (Plate 77, Figs. 3, 4.)

(2) Apparent **kinks** and **angulations** are often seen in the normal appendix owing to the plane in which a curvature is visualized. Palpation under the screen is essential for the avoidance of error in this respect.

(3) **Concretions** are seen as oval translucent areas in the ‘umen, partly or wholly outlined by a thin surrounding coating of barium emulsion.

The presence of a concretion must be regarded as suspicious, but is hardly sufficient to condemn an appendix which shows no other evidence of abnormality. In point of fact, concretions are often observed in patients who present no clinical features suggestive of appendicular disease.

(4) Involvement in **adhesions** is indicated by definite fixation of the appendix either within the abdominal cavity or, more commonly, to some adjacent part of the alimentary tract. Such fixation, if satisfactorily established, constitutes fairly conclusive evidence of disease.

(5) Retention of contents after the cæcum is void of opaque material is probably of little significance, unless prolonged for at least two days ; slighter degrees of retention may, however, be justifiably regarded as confirmatory evidence of disease in cases presenting other abnormal appearances.

(6) Localized tenderness on direct pressure. — Hurst * has shown that true visceral pain, as distinct from referred pain, depends on increased tension within the lumen of the affected portion of the gastro-intestinal tract. As pointed out when discussing the diagnosis of gastric and duodenal lesions, there is every reason to suppose that direct pressure located over any one point on these viscera cannot produce visceral pain in the absence of adhesions to the parietal peritoneum.

The appendix, however, presents a totally different problem, since the long narrow lumen obviously renders it susceptible to increased tension on direct pressure ; and it is probable that a similar effect can be obtained by pressure over a definitely obstructed coil of small intestine.

The satisfactory demonstration of tenderness in the case of the appendix is, however, by no means easy, as it depends on dissociation of visceral pain from referred tenderness of the parietes. In some cases the appendix can be displaced by palpation, and tenderness again elicited in its new position by the pressure of one finger ; it then appears justifiable to affirm the presence of true visceral pain. Visceral pain cannot be produced by pressure over a normal appendix.

In conclusion, it may be stated that a combination of two or more of the abnormalities noted above constitutes fairly conclusive evidence of appendicular disease, while complete normality of the radiographic appearances is rarely demonstrated in any but a healthy organ.

INTESTINAL STASIS

Mention has already been made, in the appropriate sections, of the rate of passage through the different portions of the alimentary tract ; and attention has been directed towards the difficulties which arise in determining variations from the normal. It would appear advisable, however, to attempt a summary of the gastro-intestinal tract as a whole from the point of view of delayed transit.

Without wishing to minimize the importance of real intestinal stasis, it must be stated that some accounts of this condition appear to be based on a misconception of the normal sequence of events, and a disregard for the variations which occur not only in different individuals but also in the same individual on different occasions.

The author has repeated the examination of a number of patients,

* " Sensibility of the Alimentary Tract."

the conditions of the two examinations being identical; in no single instance has the rate of transit of the two meals been the same. It should be obvious, therefore, that the widest possible limits must be set to allow of the variations in normality which undoubtedly occur.

Ileal stasis must be considered in relation to the emptying time of the stomach. Provided that the stomach empties in six hours, the lower ileum should contain opaque material in about three hours after ingestion of the meal, and should be void of barium by the ninth or tenth hour (i.e. three or four hours after complete gastric evacuation). The cæcum should be filled by the sixth hour. More rapid emptying of the stomach is not necessarily associated with a corresponding rapidity of ileal transit.

Delayed evacuation of the stomach, however, induces of necessity a corresponding delay in the complete passage of ileal contents into the large bowel; there appear to be no ascertainable grounds for the contention sometimes advanced that gastric delay in these cases is secondary to ileal stasis.

Ileal delay, therefore, can be described as retention of a definite residue in the small gut for more than four hours after complete evacuation of the stomach; or, utilizing the head of the opaque column, as a complete retention in the ileum at the sixth hour in spite of normal gastric evacuation.

In the absence of a definite obstructive lesion, such as adhesions, ileal delay occurs at the ileo-cæcal junction, and is apparently due to spasm or inhibited relaxation of the ileal sphincter. The cause of this neuro-muscular anomaly is still to seek; radiographic examination after such operations as appendicectomy, correction of postural kinks (which incidentally do not appear to occupy the site at which delay occurs), and colopexy does not reveal any appreciable amelioration.

Colonic stasis has already been considered in some detail, and the various types of retention have been described. Generally speaking, delay may be said to occur in the large bowel if a definite opaque residue is present seventy-two hours after ingestion of the meal, in spite of normal evacuation of the stomach and small intestine. Gross delay in emptying of the stomach or ileum will tend to produce an apparent stasis in the colon, and allowance must therefore be made for any such abnormality observed at the earlier examinations.

Colonic stasis appears to be due, in the absence of an organic obstructive lesion, to atony of the musculature; it is possible that spasm of the distal portion of the bowel is sometimes concerned, but this is probably of rare occurrence.

Rectal retention results from an acquired insensibility of the rectum to distension, and is not directly comparable to the colonic type of disability.

THE BILIARY TRACT. THE SOLID ABDOMINAL VISCERA

THE BILIARY TRACT

PERSISTENT efforts have been made to improve the radiographic technique of investigating the biliary tract, and slow but definite progress is being achieved. At the present time the following methods are available :

(1) Direct evidence may be obtained by—
    (a) Demonstration of biliary calculi.
    (b) Demonstration of the gall-bladder and calculi after intraperitoneal inflation with oxygen.
    (c) Demonstration of the gall-bladder by introducing into the circulation an opaque substance excreted by the liver.

(2) Indirect evidence may be obtained from an opaque-meal examination of the stomach and duodenum.

(1) **Direct evidence.**—(a) The vast majority of biliary calculi are, for all practical purposes, non-opaque to X-radiation ; that is, they present an opacity equal to or less than that of the surrounding soft tissues. Successful demonstration depends, therefore, on the deposition of opaque salts upon the surface of the calculi. Such deposition occurs in quantities sufficient to produce a definitely demonstrable opacity in not more than 10 or 15 per cent. of cases.

Preparation of the patient is carried out as for investigations of the urinary tract—i.e. a mild aperient is ordered for two nights running, the patient takes as little food as possible on the day before the examination, and only a small quantity of tea and toast as early as possible the following day before visiting the X-ray room.

Skiagrams are taken in the antero-posterior and postero-anterior planes ; should these show any suspicious opacity a lateral view is obtained. It is essential that respiratory movements should be completely arrested during the exposures.

Demonstrable biliary calculi are characteristically seen as ring-shadows enclosing a central translucent area. The appearance depends on the fact that the radiation passing through the circumference of

the stone, in whichever plane it is seen, are opposed by a thicker layer of opaque salts than that which traverses the more central portion of the calculus. These ring-shadows may be round or irregularly angular, and in the latter case are usually multiple, the straight-sided outlines forming a faithful representation of the faceted opposed surfaces of the calculi. These centrally translucent ring-shadows are so characteristic of biliary calculi that no difficulty in diagnosis is likely to arise. (Plate 78, Fig. 1.)

Single biliary calculi, however, sometimes present a round, uniform or faintly laminated opacity, owing to the admixture of cholesterol with opaque salts. In these circumstances great difficulty will be experienced in differentiation from calculus in the right kidney. (Plate 78, Fig. 2.) Should the calculus be in the gall-bladder a lateral view will generally prove conclusive by showing the shadow well in front of the anterior margin of the spinal column, whereas renal calculi are generally superimposed on the bone-shadow. A calculus impacted in the common bile-duct will approximate in position to a renal calculus in the lateral view, but will be slightly internal to the normal renal pelvis in the antero-posterior view. These cases will, however, often necessitate a pyelographic examination for complete elucidation. (Plate 78, Fig. 3.)

(b) The method of oxygen-inflation of the peritoneal cavity (pneumo-peritoneum) is described below. After such inflation the gall-bladder can be plainly demonstrated in many cases, and pure cholesterin calculi may occasionally be represented as central translucent areas, owing to their greater translucency to X-radiation than the surrounding bile. The author has had no personal success in demonstrating biliary calculi by this method, except in cases where ring-shadows were discernible by ordinary radiography ; and other workers have recorded similar lack of success. It would appear, therefore, that pneumo-peritoneum is of little value in the diagnosis of biliary lesions.

(c) Encouraging results have been obtained by the use of sodium tetra-iodo-phenolphthalein and sodium tetra-bromphenolphthalein. These substances are synthetic dyes which possess considerable opacity to X-radiation, and, if introduced into the systemic or the portal circulation, are excreted by the liver.

The dye may be administered as an intravenous injection, or may be taken by the mouth enclosed in gelatin capsules.

The intravenous method is at present attended with a much higher percentage of successful results, but is not infrequently followed by rather severe manifestations of vaso-motor shock.

The quantity to be injected is decided by the body-weight of the patient, 0·04 grain per kilogram being usually allowed. A freshly

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prepared 5 per cent. solution in normal saline is autoclaved, diluted with normal saline to 2 per cent., and then injected into a superficial vein, either by a syringe or by gravity. It is advisable to inject a few cubic centimetres of plain saline both before and after the dye solution, to ensure that none of the latter escapes into the cellular tissues—a mishap apt to result in a severe inflammatory reaction. The patient takes no solid food for six hours before or after the injection, but considerable quantities of sodium bicarbonate are usually administered. Radiographic examination is made at six and ten hours, and the gall-bladder, if normal, should be seen filled with the dye. A meal containing a preponderance of fat is then given, and is followed by further skiagrams in one, three, and twenty-four hours.

The *normal* gall-bladder fills with the dye almost invariably, and presents a fairly dense, uniform, pear-shaped shadow ; this shadow undergoes appreciable diminution in size and increase in density within an hour of a fatty meal, and disappears before the twenty-fourth hour.

The *abnormal* gall-bladder frequently does not fill with a recognizable quantity of the dye, and this failure to demonstrate a gall-bladder shadow constitutes the most important evidence of a biliary lesion. In other cases the gall-bladder shadow may be visible but unduly faint, or there may be no diminution in size after taking the fatty meal. Calculi in a gall-bladder filled with the dye are seen as translucencies.

A remarkable degree of accuracy in diagnosis has been obtained by means of the intravenous injection, but the frequent occurrence of unpleasant and even alarming symptoms constitutes a serious disadvantage.

The oral method of administration is rarely followed by any adverse symptoms of real moment, though many patients complain of nausea, and vomiting is not uncommon.

The dye is given with the evening meal to a total dosage of 5 grains, lesser quantities being allowed for thin subjects. Large quantities of water are taken with the capsules, and may also be allowed during the night, but no further solid food is given until after the first radiographic examination, some ten or twelve hours later. The gall-bladder should then be filled, and the subsequent procedure is identical with that already described. (Plate 78, Fig. 4.)

For the purpose of diagnosis, attention is directed towards the same features as in the intravenous method. Unfortunately, however, the most valuable diagnostic sign of disease—i.e. failure of the gall-bladder to fill with the dye—is much less reliable after oral administration than after intravenous injection. It is to be hoped that further investigations will result in a modification in technique or in the composition of the dye, whereby this disadvantage will be overcome.

Fig. 1.—Biliary calculi and duodenal ulcer.

Fig. 2.—Biliary calculus of uni
opacity.

Fig. 3.—Normal pyelogram: a biliary calculus lies
external to the renal pelvis.

Fig. 4.—Normal gall-bladder filled witl

PLATE 78.

Fig. 1.—Depression in duodenal cap (half-shadow) due to pressure of pathological gall-bladder.

Fig. 2.—Displacement outwards of duodenum by adhesions to gall-bladder.

PLATE 79.

(2) **Indirect evidence** of a lesion of the biliary tract can be obtained in a considerable proportion of cases from examination of the barium-filled stomach and duodenum.

This evidence may consist either of a pressure deformity in the pyloric antrum or duodenal cap, or of displacement of the first and second parts of the duodenum.

The *pressure deformity* is indicative of abnormal distension of the gall-bladder, and consists of a concave filling-defect with smooth regular outline, known as the " half-shadow." This defect is most commonly seen in the duodenal cap (Plate 79, Fig. 1), but may sometimes be noted in the upper or lower borders of the pyloric antrum. It fulfils the essential characteristic of a deformity produced by external pressure in that it varies with change of posture. The presence of a well-marked half-shadow in the pyloric antrum or duodenal cap may be taken as very strong evidence of a biliary lesion.

Fixed *displacement* of the first part of the duodenum to the right, and of the second part of the duodenum upwards and to the right, is indicative of adhesions or peritoneal veils between these parts and the biliary structures. Such adhesions are, however, very common in cases of old duodenal ulceration, while the avascular peritoneal veil which so often unites the hepatic flexure, gall-bladder, duodenum and pyloric antrum appears to possess no definite clinical significance. Hence it cannot be held that very great importance attaches to these duodenal displacements as regards disease of the biliary tract. (Plate 79, Fig. 2.)

It has also been stated that a reduplication of the proximal transverse colon, producing an apparent double hepatic flexure, is indicative of adhesions or mesenteric contraction due to a biliary lesion. Such double flexures are, however, exceedingly common, and it is very doubtful if any diagnostic importance can be assigned to them.

The Solid Abdominal Viscera

Radiography ordinarily affords little, if any, information regarding the solid abdominal viscera, with the exception of the kidneys. This is due to the fact that the individual viscera present no opacity distinct from that of the surrounding tissues. *Injection of oxygen into the peritoneal cavity* results in the solid organs being separated by the translucent gas, and subsequent X-ray examination in suitable positions of the patient will then reveal the size and shape of the liver, gall-bladder, spleen, kidneys, uterus, ovaries and Fallopian tubes. Adhesions and tumours may also be demonstrated.

The process of injection is simple, but not devoid of pain.

The site of choice for puncture is usually a point about one inch below and to one or other side of the umbilicus. Local anæsthesia

is induced in the muscles and fasciæ, and if possible in the extra-peritoneal areolar tissue, and a hollow needle of the size used for lumbar puncture is then thrust straight downwards along the anæsthetized tract. The position of the point of the needle can readily be gauged from the successive resistances imposed by the anterior and posterior rectal sheaths and the parietal peritoneum. The needle is then connected with the receptacle containing the oxygen, which may be either a rubber bag or the actual cylinder ; in either case a cotton-wool filter should be interposed. Entrance of gas into the abdominal cavity is soon indicated on screen examination by separation of the liver from the diaphragm, but the injection is continued until the patient complains of distension. The needle is then withdrawn.

Radiographic technique is directed towards obtaining the maximum quantity of gas around the organs to be examined. Hence the majority of skiagrams are obtained with the patient in the prone position. Accumulation of the gas around the liver, gall-bladder and spleen is assured by raising the shoulders (Plate 80, Fig. 1), while examination of the pelvic organs requires elevation of the pelvis (Plate 80, Fig. 2). Adhesions between the anterior abdominal parietes and the stomach or intestines are seen as opaque bands crossing the gas-filled portion of the abdomen in a lateral view of the supine position.

After the necessary skiagrams have been obtained the needle can be reinserted and some of the gas allowed to escape ; absorption takes place within forty-eight hours if the gas is left *in situ.* The patient should be kept in bed for twenty-four hours after the injection.

This method of examination is by no means free from danger, since several deaths have been reported, in addition to a number of minor accidents ; while in the most favourable circumstances the injection is productive of a certain amount of pain and discomfort. It is, moreover, exceedingly rare to obtain any *useful* information which could not be elicited by less drastic means.

Taking these facts into consideration, it would appear that pneumo-peritoneum as an aid to radiography should be recommended only in very exceptional circumstances.

Fig. 1.—Pneumoperitoneum: normal liver and kidney.
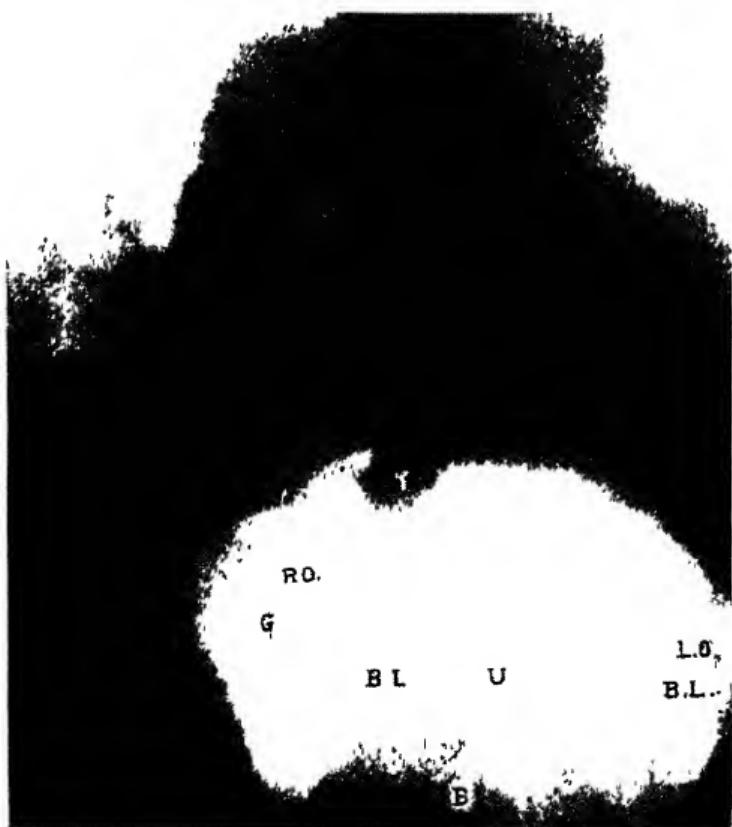
Fig. 2.—Pneumoperitoneum: pelvic organs.

B, Bladder; U, uterus; B L, broad ligament, R.O, right ovary;
L O, left ovary; G, calcified gland.

PLATE 80.

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